SPECIFICATION NO. 118A

APRIL 22, 1963

AIRPLANE DETAIL SPECIFICATION

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LIFT FAN FLIGHT RESEARCH AIRCRAFT PROGRAM

CONTRACT DA44-177-TC-715

AIRPLANE DETAIL SPECIFICATION

SPECIFICATION NO. 118A

APRIL 22, 1963

GENERAL ELECTRIC COMPANY

FLIGHT PROPULSION LABORATORY DEPARTMENT

CINCINNATI 15, OHIO

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LIST OF SYMBOLS AND ABBREVIATIONS

β_s	-	Fan Exit Louver Stagger Angle
β_v	-	Fan Exit Louver Vector Physical Angle
CG	-	Aircraft Center of Gravity
CPS	-	Cycles per Second
g	-	Acceleration due to Gravity
L/W	-	Lift Divided by Weight Ratio
RPM	-	Gas Generator Revolutions per Minute
R/C	-	Rate of Climb
TAS	-	True Airspeed
V_s	-	Stalling Speed
V_{min}	-	Minimum Aircraft Velocity
V_{max}	-	Maximum Aircraft Velocity
α	-	Angle of Attack
δ_F	-	Flap Angle
P_{T_c}	-	Total Pressure at Compressor Face
P_{T_o}	-	Total Pressure Free Stream
MLG	-	Main Landing Gear
NLG	-	Nose Landing Gear
qmax	-	Maximum Dynamic Pressure
$\sigma^{1/2}$	-	Atmospheric Density Ratio
M	-	Mach Number
n_z	-	Load Factor
v_g	-	Vertical Gust

1. SCOPE. -

1.1 This specification covers the following aircraft:

Service Model Designation:	XV-5A
Ryan Aeronautical Company Model:	143
Crew:	1 Pilot, or 1 Pilot and passenger or observer,
Engines:	2 General Electric J85-5 Turbojets, combined with 2 wing fans, designated as the X353-5B convertible propulsion system, and 1 X376 pitch fan.

1.1.1 The mission of the aircraft is to evaluate flight characteristics of the lift-fan propulsion system in VTOL and conventional flight modes.

2. APPLICABLE DOCUMENTS. -

2.1 The following specifications, standards, and publications current on 1 June 1961 (except where noted) shall be used as guides in design of the aircraft detailed by this specification.

2.1.1 Specifications. -

MIL-A-8806 (ASG)	Acoustical Noise Level in Aircraft, General Specification for.
MIL-A-8860	Airplane Strength and Rigidity, General Specification for.
MIL-A-8870	Airplane Strength and Rigidity, Vibration, Flutter, and Divergence.
MIL-B-5087A (ASG)	Bonding Electrical, for Aircraft.
MIL-B-8584A	Brake Systems, Wheel, Aircraft, Design of.
MIL-C-5041B	Casings, Tire and Tubeless Tires, Aircraft Pneumatic.

MIL-D-7006A (ASG)	Detecting Systems, Fire, Aircraft, Continuous Type, Installation of.
MIL-E-25499A	Electrical Systems, Aircraft, Design of, General Specification for.
MIL-E-26144	Electrical Power, Missile, Characteristics and Utilization, General Specification for.
MIL-E-5272C	Environmental Testing, Aeronautical and Associated Equipment, General Specification for.
MIL-E-5400E (ASG)	Electronic Equipment, Aircraft, General Specification for.
MIL-E-7016C	Electric Load and Power Source Capacity, Analysis of, Method for Aircraft and Missiles.
MIL-E-7017	Electrical Load Analysis, Method for Aircraft. DC.
MIL-E-7080A	Electric Equipment, Piloted Aircraft Installation and Selection of, General Specification for.
MIL-F-25352	Flutter, Divergence, and Reversal in Aircraft, Prevention of.
MIL-F-8785	Flying Qualities of Piloted Airplanes:
MIL-H-5440C	Hydraulic Systems, Aircraft Types I and II, Design, Installation, and Data Requirements for.
MIL-H-8501	Helicopter Flying Qualities, Requirements for.
MIL-I-6140A (ASG)	Insignia, National Aircraft.
MIL-I-7032D (ASG)	Inverter, Aircraft, General Specification for.
MIL-J-8711	Jack Pads, Aircraft, Design and Installation of.
MIL-L-5667A (ASG)	Lighting Equipment, Aircraft Instrument Panel, General Specification for Installation of.
MIL-L-6503D	Lighting Equipment, Aircraft, General Specification for Installation of.

MIL-L-6880B	Lubrication of Aircraft, General Specification for.
MIL-P-11747	Painting, Marking, and Insignia for U. S. Army Aircraft, General Specification for.
MIL-Q-9858	Quality Control System Requirements.
MIL-S-6252D	Specifications, Detail, Fixed Wing Aircraft, Preparation of.
MIL-S-8552A	Strut, Aircraft Shock Absorber, Air-Oil Type.
MIL-W-25140 (ASG)	Weight and Balance Control Data for Airplanes and Rotorcraft.
MIL-W-5013E	Wheel and Brake Assemblies, Aircraft.
MIL-W-5088B (ASG)	Wiring, Aircraft, Installation of.

2.1.2 Standards. -

MIL-STD-210A	Climatic Extremes for Military Equipment.
MIL-STD-254 (ASG)	Weight and Balance Reporting Forms for Aircraft.

2.1.3 Publications. -

Air Force-Navy Aeronautical Bulletin 143	Specifications and Standards, use of.
Air Force-Navy Aeronautical Bulletin 421	Atmospheric Properties, Extreme Cold and Hot, Standard for Aeronautical Design.
MIL Handbook-5	Strength of Metal Elements.
U. S. Army TCREC-RC	Request for Quotation, Planning Purposes, for.

G. E. Specification 112, dated 15 Jan. 1962	X353-5B Convertible Propulsion System.
G. E. Specification 113, dated 1 Mar. 1962	X376 Pitch Fan.
Ryan Specification 14359-1, dated 5 Jul. 1962	Aircraft finish specification.
Ryan Report 62B062 - Appendix A	XV-5A Flying Qualities
Ryan Report 62B094, dated 1 Jul. 1962	Structural Design Criteria.

3. REQUIREMENTS. - The characteristics and performance defined in this specification shall be considered as design objectives.

3.1 Characteristics. - The aircraft shall be a mid-wing, lift-fan powered research aircraft. It shall be propelled by two G. E. X353-5B propulsion systems. It shall be capable of conventional wing-supported flight at high subsonic speeds. The aircraft shall also be capable of VTOL and STOL in the fan-supported flight mode. The aircraft shall be capable of transition from zero horizontal speed to high horizontal speed and return through transition to hovering flight. It shall be capable of conventional take-off and landing. During wing-supported flight, conventional control surfaces shall be utilized. During fan supported flight, control shall be accomplished through modulation of the air flow through the fans.

3.1.1 Aircraft Three View Drawing. - See Figure 1.

3.1.1.1 Aircraft Cutaway Drawing. - See Figure 2.

3.1.2 Aircraft Performance. - Aircraft flight performance shall be in accordance with RFQ TREC-RC, Annex C, dated 31 March 1961. These performance requirements and the expected flight tests of the aircraft shall provide the basis for the performance data to be presented.

3.1.2.1 Designed Aircraft Performance. -

3.1.2.1.1 VTOL Performance. - Net lift to design gross weight ratio shall not be less than 1.05 at 2,500 feet, 93.7 degrees Fahrenheit (ANA 421 Hot Day), after control power extraction. Net lift is defined as the summation of vertical forces in trimmed hover condition in or out of ground effect, whichever is less.

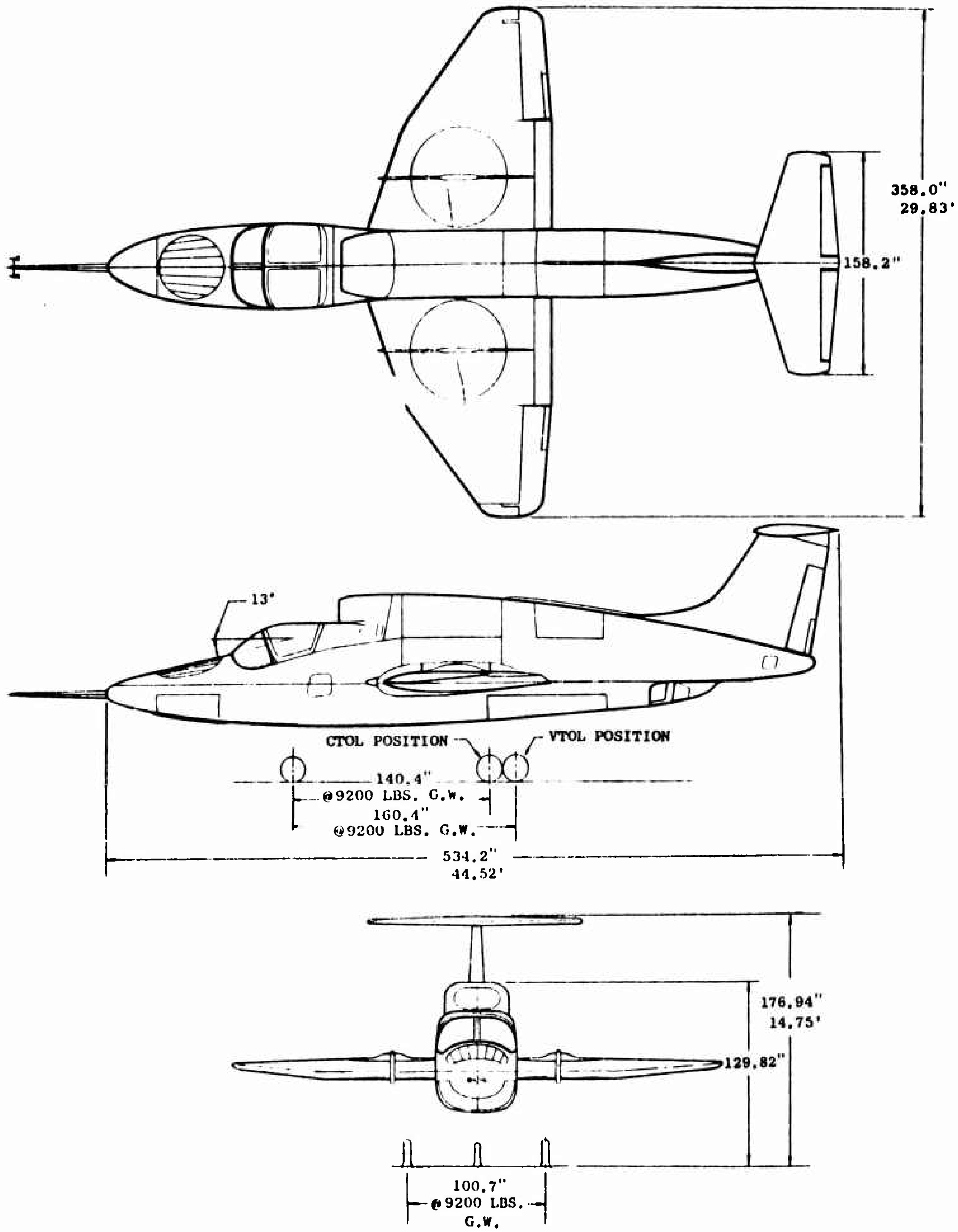

Figure 1 Three View Drawing

1. PITOT MAST
2. FIBERGLAS NOSE CONE
3. G.E. X376 PITCH CONTROL FAN
4. NOSE FAN T: ST CONTROL DOOR
5. NOSE FAN INLET CLOSURE DOORS
6. CANOPY
7. NOSE FAN SUPPLY DUCT
8. RUDDER PEDALS
9. INSTRUMENT PANEL
10. CONVENTIONAL CONTROL STICK
11. OBSERVER'S EJECTION SEAT
12. NOSE LANDING GEAR
13. THROTTLE QUADRANT
14. PILOT'S EJECTION SEAT
15. COLLECTIVE LIFT STICK
16. HYDRAULIC EQUIPMENT COMPARTMENT
17. SINGLE SPLIT ENGINE INLET DUCT
18. ELECTRICAL EQUIPMENT COMPARTMENT
19. HYDRAULIC PUMP
20. FUEL TANK
21. GENERATOR
22. RIGHT WING
23. G. E. J85-5 GAS GENERATOR
24. AILERON. R. H.
25. CROSS-OVER DUCT
26. WING FAN EXIT LOUVER ACTUATORS
27. DIVERTER VALVE
28. WING FAN INLET CLOSURE DOORS
29. G. E. X353-5 LIFT FAN
30. ENGINE TAIL PIPE
31. TWO POSITION MAIN LANDING GEAR
32. LEFT WING
33. AILERON. L. H.
34. WING FLAP. L. H.
35. THRUST SPOILERS
36. VERTICAL FIN
37. FULL MOVEABLE HORIZONTAL STABILIZER
38. SPACE PROVISION FOR ANTI-SPIN CHUTE
39. RUDDER
40. ELEVATORS

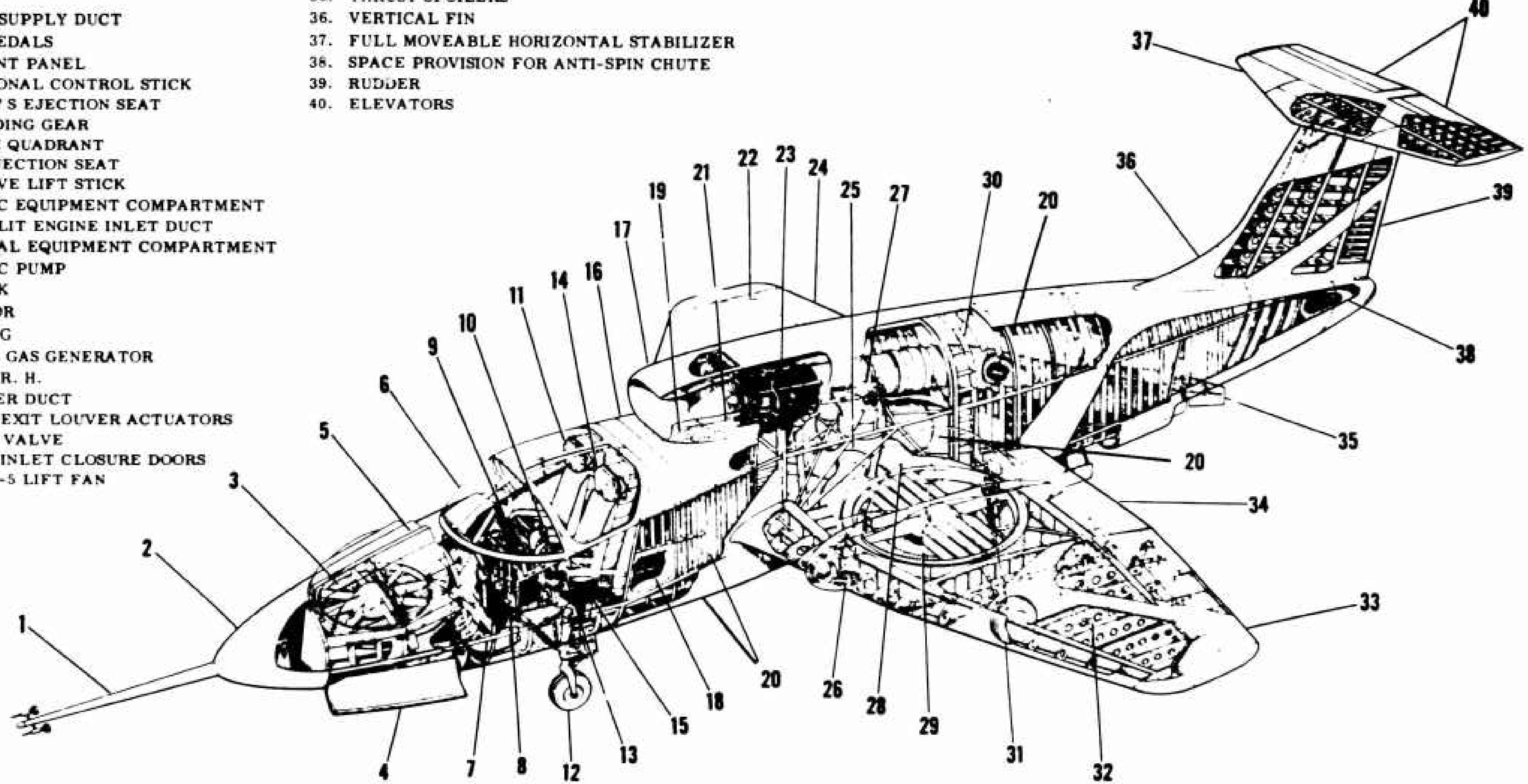

Figure 2. Aircraft Cutaway Drawing

3.1.2.1.2 VTOL Endurance Missions. -

3.1.2.1.2.1 Mission A. - The aircraft shall be capable of the following endurance at 2,500 feet, ANA 421 Hot Day, based on vertical take-off at a net lift to design gross weight ratio of 1.05.

(a) 5 minutes hover out of ground effect, plus (b).

(b) 45 minutes flight at best endurance with both engines operating, plus (c).

(c) Reserve fuel allowance of 10 percent initial fuel weight.

3.1.2.1.2.2 Mission B. -The aircraft shall be capable of the following endurance at 2,500 feet, ANA 421 Hot Day, based on vertical take-off at a net lift to reduced gross weight ratio of 1.2.

(a) 5 minutes hover out of ground effect, plus (b).

(b) 20 minutes conventional flight at best endurance with both engines operating, plus (c).

(c) Reserve fuel allowance of 10 percent initial fuel weight.

3.1.2.1.2.3 Flight endurance at 2,500 feet, ANA 421 Hot Day, as a function of take-off weight is shown in Figure 3. Missions A and B hover time and fuel reserve requirements are included. A flight endurance capability of 28 minutes is indicated for the design gross weight condition of Mission A. Mission B shows an endurance of 11 minutes.

3.1.2.1.3 Transition Characteristics. - The aircraft shall be capable of vertical take-off, transition to conventional flight (out of ground effect), and transition back to vertical landing. The aircraft shall be designed to permit stopping or reversing of transition at any point, and return to the initial flight mode. The aircraft shall be capable of acceleration by the lift-fan to 120 percent of V_{stall} (based on inlet and exit louvers closed). A safe stall margin shall be provided during conversion between fan and conventional flight modes. The aircraft shall be capable of performing the entire transition to or from conventional flight at constant altitude. Transition shall be possible with landing gear extended or retracted.

3.1.2.1.3.1 Maximum speeds for one and two engines, operating in the fan flight mode, are presented as a function of gross weight in Figure 4. The landing gear is assumed retracted. Flap deflection, and effect of angle of attack are also indicated. Speed curves of 100 and 120 percent of power-off stall speed are provided. A speed capability equal to the structural limit speed of the fan system is indicated for weights up to and beyond 14,000 pounds.

3.1.2.1.3.2 Speed and power trim data for fan-flight mode are given in Figures 5 and 6 for aircraft weights of 9200 pounds and 12,500 pounds. These data are presented as a function of exit louver deflection. The effect of angle of attack is also shown.

3.1.2.1.4 Horizontal Speed Capability. - The aircraft shall possess a horizontal flight speed capability of 450 knots (TAS) at 2,500 feet ANA 421 Hot Day.

3.1.2.2 Additional Performance. -

3.1.2.2.1 Hovering Performance. - Hover lift capability is given in Figure 7 as a function of altitude for standard ARDC model atmosphere, and hot day conditions.

3.1.2.2.2 Conventional Flight Performance. - Conventional flight cruise, climb, and speed performance estimates are based on an ARDC model atmosphere except where noted.

3.1.2.2.2.1 Range performance as a function of initial weight is given in Figure 8 using an altitude limit of 10,000 feet. The range mission is described in the figure. Speed for maximum range at 10,000 feet is given in Figure 9.

3.1.2.2.2.2 Flight endurance versus initial weight is presented in Figure 10 using an altitude limitation of 10,000 feet. Endurance mission is described in the figure. Airspeed for maximum endurance at 10,000 feet is presented in Figure 11.

3.1.2.2.2.3 Maximum rate of climb for various aircraft weights as a function of altitude is presented in Figure 12. Speed for maximum rate of climb as a function of altitude is given in Figure 13.

3.1.2.2.2.4 A speed-altitude envelope for military power is presented in Figure 14.

3.1.2.2.2.5 Available and required thrust for flight at sea level, 2500 feet, and 5000 feet in ARDC standard atmosphere is presented in Figures 15, 16, and 17 as a function of gross weight. Similar data for the hot atmosphere (ANA Bulletin No. 421) is given for altitudes of 2500 feet and 5000 feet, in Figures 18 and 19.

3.1.2.2.3 Minimum Flight Recovery Envelope. - Minimum flight recovery envelope for one engine inoperative in fan-flight mode, is shown in Figure 20. The envelope is based on accomplishment of a recovery flare with 10 feet per second rate of descent at ground contact. The data are based on an aircraft weight of 9200 pounds.

3.1.2.2.4 STOL Performance. - Runway take-off performance for the lift-fan mode is shown in Figure 21 as a function of gross weight. Data for take-off over a 50 foot obstacle is presented for sea level, and 2500 feet altitudes.

3.1.2.2.5 Conventional Take-Off Distances. - Conventional take-off distances over a 50 foot obstacle are presented in Figure 22. Data for take-off at sea level, and 2500 feet altitudes are presented as a function of aircraft weight. Take-off performance is based on a 30 degree flap setting, and military power.

3.1.2.2.6 Conventional Landing Distances. - Conventional landing distances over a 50 foot obstacle are presented in Figure 23. Data for sea level and 2500 foot altitudes are shown versus aircraft weight. Landing performance is calculated using 45 degree flap setting, and idle power.

3.1.2.2.7 Ferry Range. - Ferry-range, based on airspeeds and altitudes for maximum range with two engines operating, and an initial weight of 12,684 pounds, is presented in Figure 24.

3.1.2.3 Aircraft Engine Specification. - Aircraft performance specified herein is based on General Electric X353-5B Propulsion System Specification 112, dated 15 January 1962, and X376 Pitch Fan Specification 113, dated 1 March 1962.

TAKE-OFF WEIGHT VERSUS ENDURANCE
2500 FEET ANA 421 HOT DAY
CONVENTIONAL FLIGHT ENDURANCE
FOLLOWING 5 MINUTES OF HOVER
INCLUDES 10% FUEL RESERVE
GAS GENERATOR NOSE FAN BLEED = 10.6 PERCENT

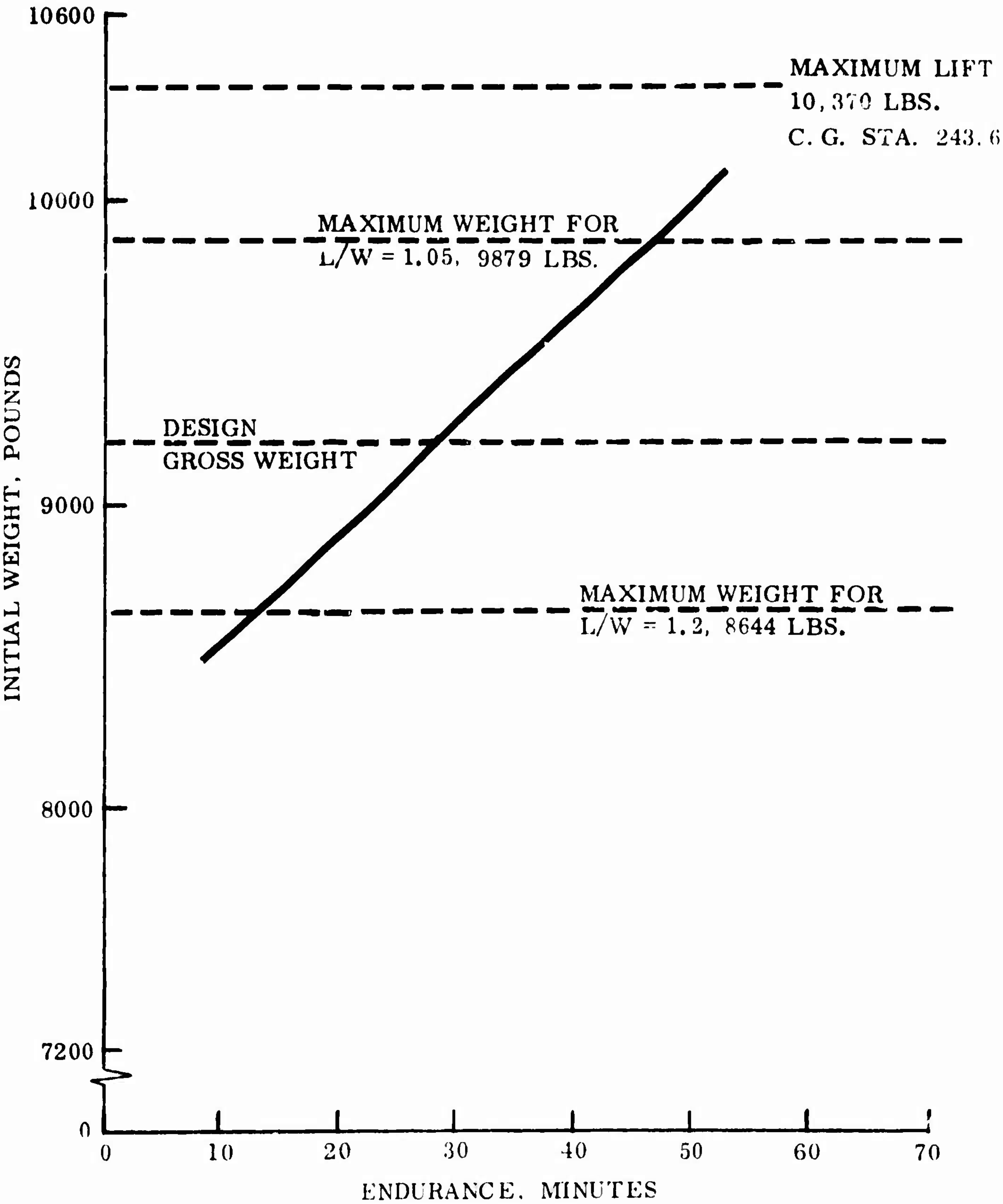

Figure 3 Take-off Weight Versus Endurance

FAN MODE MAXIMUM FLIGHT BOUNDARIES

SEA LEVEL ARDC STANDARD DAY

GEAR UP, MILITARY POWER

CONSTANT ALTITUDE—UNACCELERATED FLIGHT

$\delta_f = 45^\circ$, $\beta_v = 45^\circ$

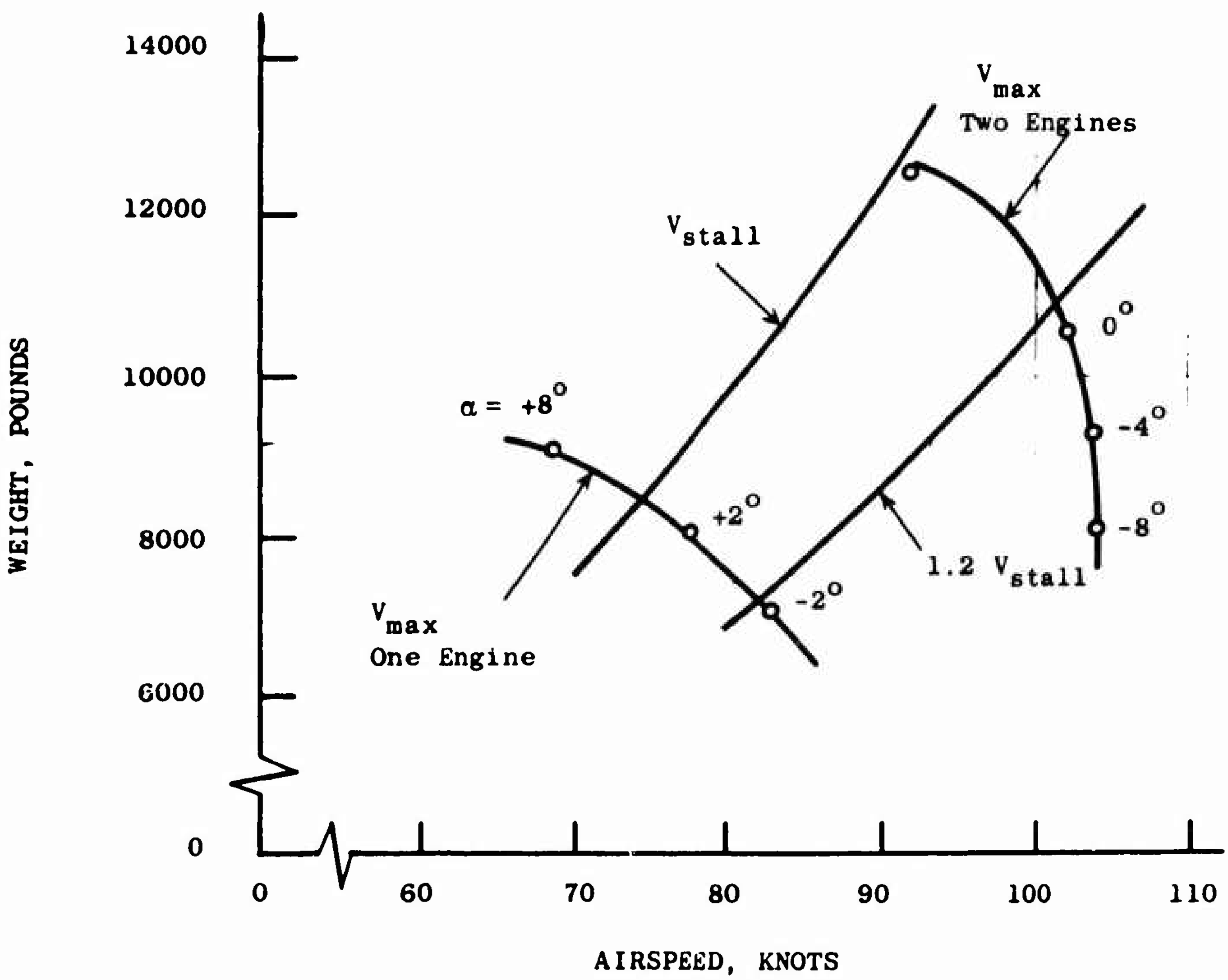

Figure 4. Fan Mode Maximum Flight Boundaries

TRANSITION TRIM CHARACTERISTICS

CONSTANT ALTITUDE-UNACCELERATED FLIGHT

SEA LEVEL ARDC STANDARD DAY

GEAR DOWN, G.W. = 9200 POUNDS, $\delta_f = 45^{\circ}$

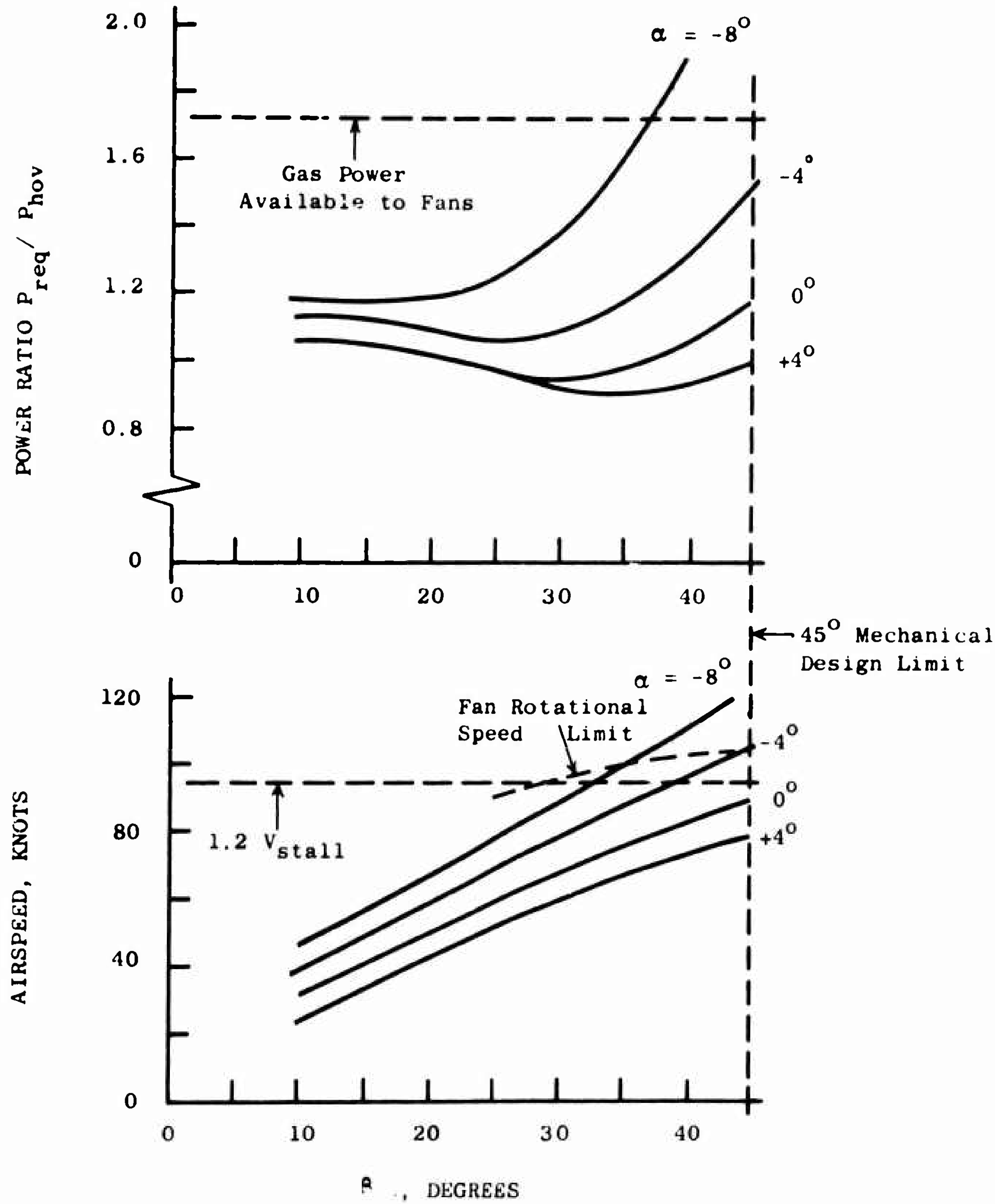

Figure 5. Transition Trim Characteristics, GW = 9200 lbs.

TRANSITION TRIM CHARACTERISTICS

CONSTANT ALTITUDE-UNACCELERATED FLIGHT

SEA LEVEL ARDC STANDARD DAY

GEAR DOWN, G.W. = 12,650 POUNDS, $\delta_f = 45^{\circ}$

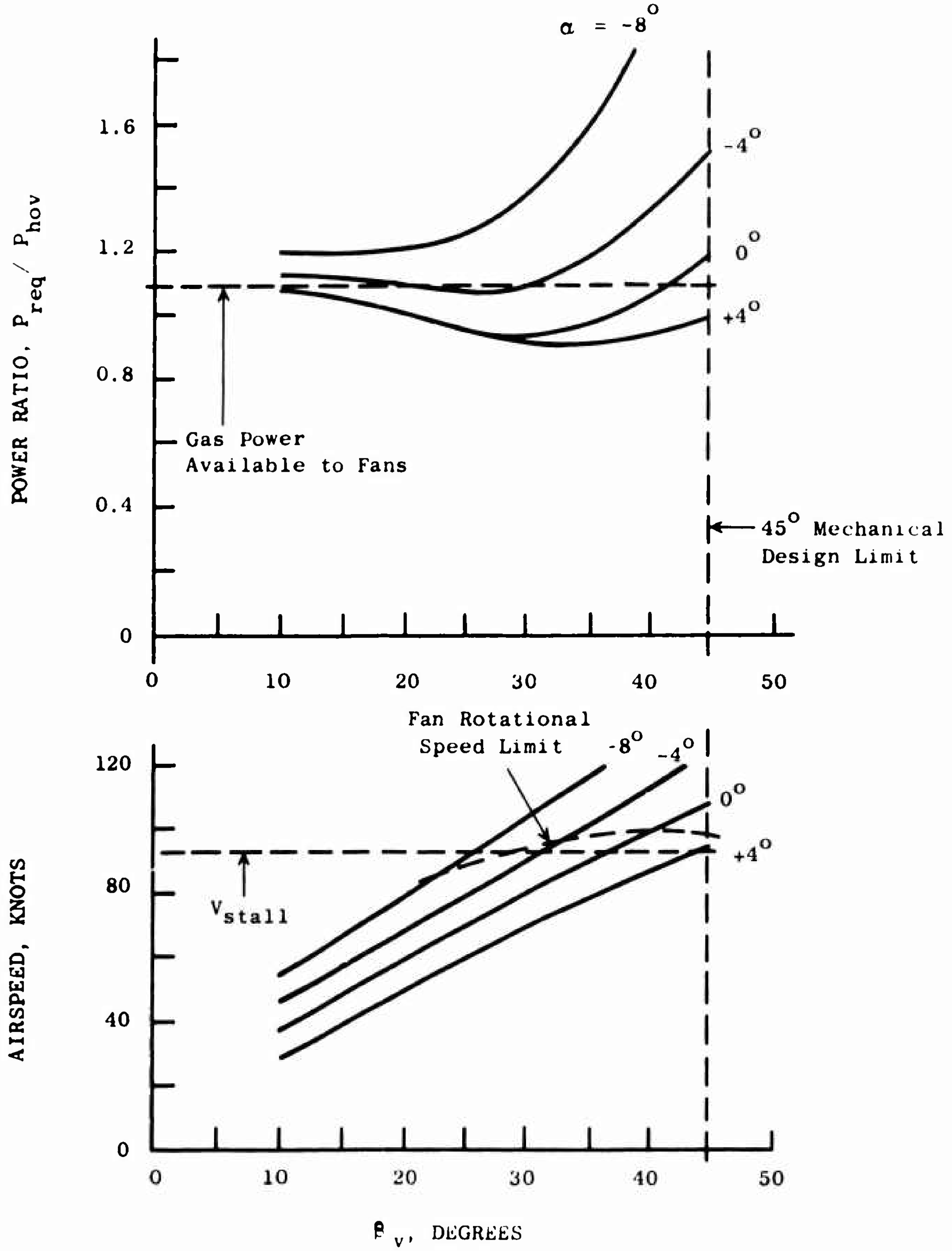

Figure 6. Transition Trim Characteristics, G.W. = 12,650 lbs.

TOTAL TRIMMED LIFT VERSUS ALTITUDE
GAS GENERATOR NOSE FAN BLEED = 10.6 PERCENT
ZERO FORWARD VELOCITY
CENTER OF GRAVITY = STA. 243.7

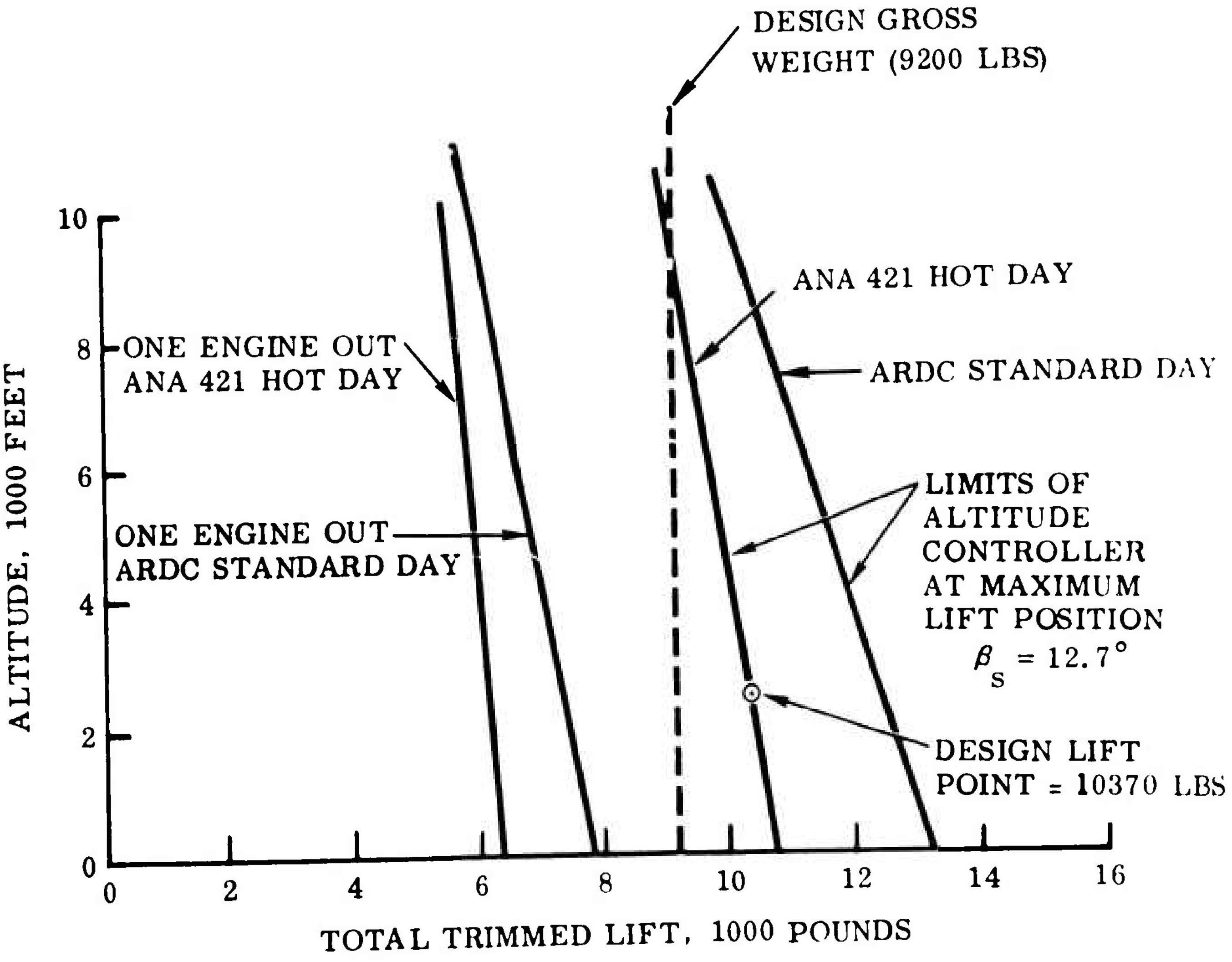

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Figure 7 Total Trimmed Lift Versus Altitude

DISTANCE TRAVELED VERSUS INITIAL WEIGHT
CONVENTIONAL TAKE-OFF AND LANDING
CRUISE ALTITUDE = 10,000 FEET
TWO ENGINES OPERATING
ARDC STANDARD DAY

MISSION DESCRIPTION:

1. FUEL ALLOWANCE FOR STARTING ENGINES, TAKE-OFF, AND ACCELERATE-TO-CLIMB SPEED IS POUNDS OF FUEL USED IN 5.0 MINUTES WITH NORMAL POWER AT TAKE-OFF ALTITUDE (95% RPM).
2. CLIMB ON COURSE TO 10,000 FEET WITH MILITARY THRUST.
3. CRUISE AT AIRSPEEDS FOR MAXIMUM RANGE UNTIL 10% OF INITIAL FUEL REMAINS.
4. 10% OF INITIAL FUEL IS ALLOWED FOR RESERVE AND LANDING.

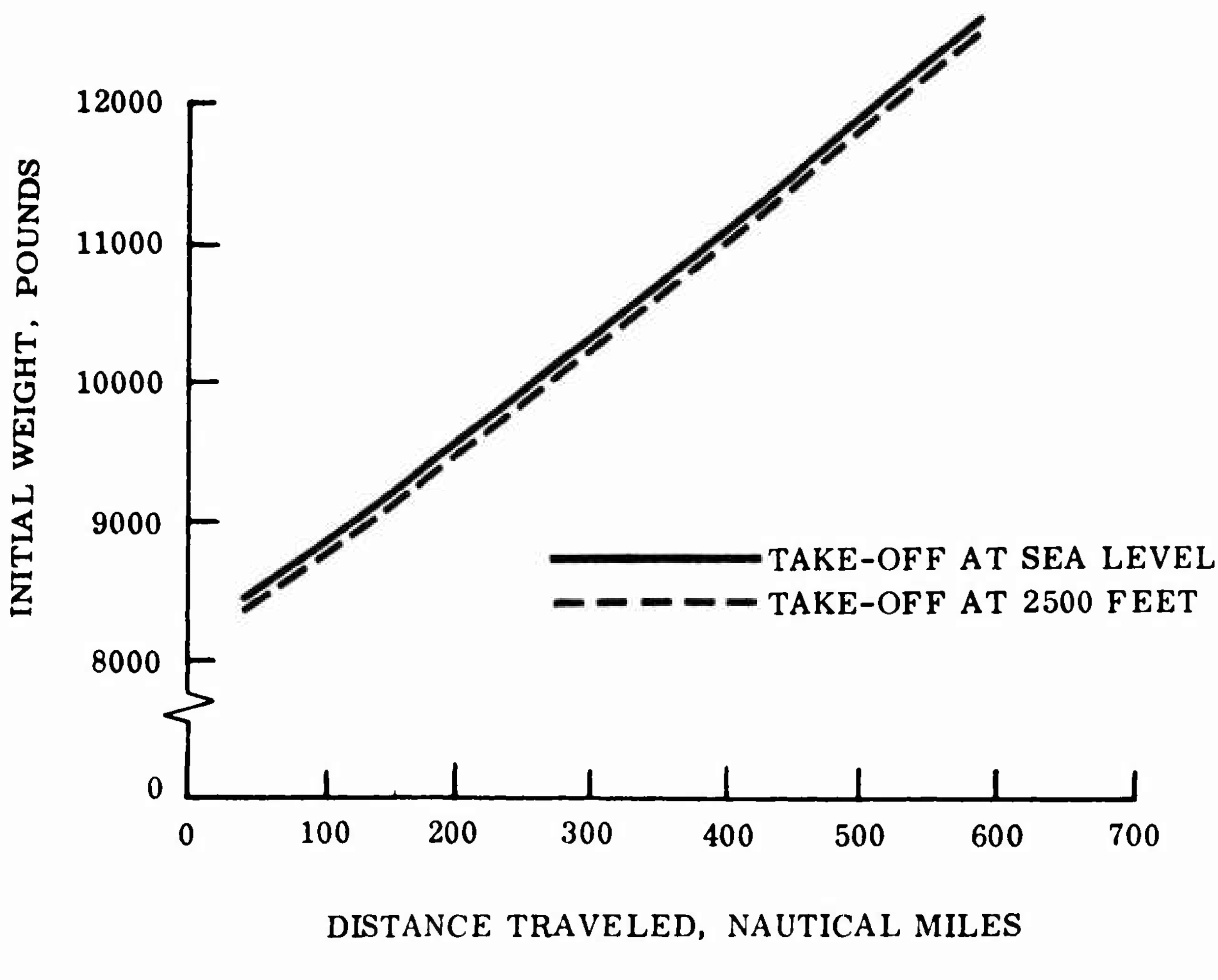

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Figure 8 Distance Traveled Versus Initial Weight

VELOCITY FOR MAXIMUM DISTANCE VERSUS WEIGHT
CONVENTIONAL TAKE-OFF AND LANDING
CRUISE ALTITUDE = 10,000 FEET
TWO ENGINES OPERATING
ARDC STANDARD DAY

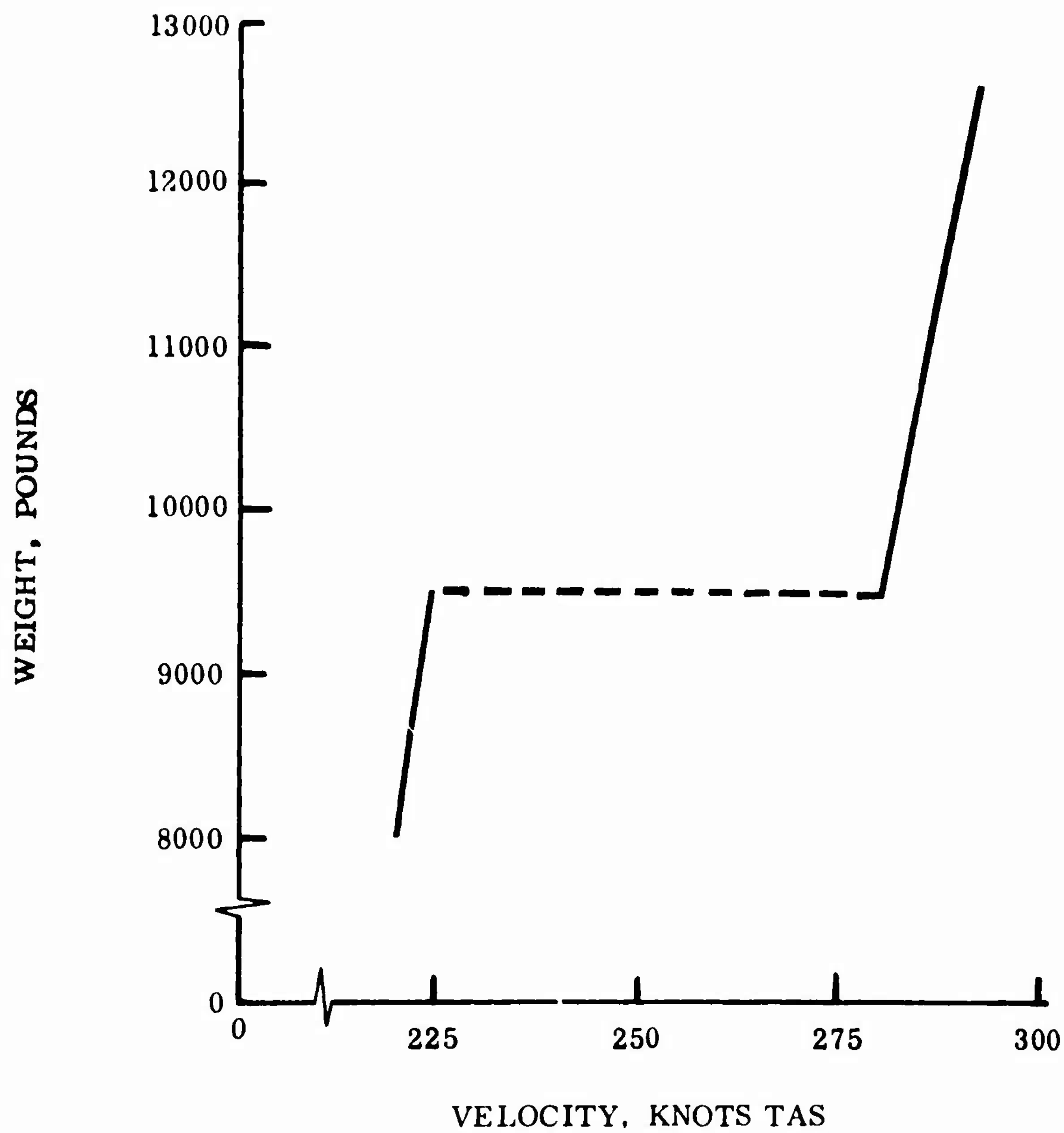

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Figure 9 Velocity for Maximum Distance Versus Weight

MAXIMUM FLIGHT ENDURANCE VERSUS INITIAL WEIGHT
CONVENTIONAL TAKE-OFF AND LANDING
CRUISE ALTITUDE = 10,000 FEET
TWO ENGINES OPERATING
ARDC STANDARD DAY

MISSION DESCRIPTION:

1. FUEL ALLOWANCE FOR STARTING ENGINES, TAKE-OFF, AND ACCELERATE-TO-CLIMB SPEED IS POUNDS OF FUEL USED IN 5.0 MINUTES WITH NORMAL POWER AT TAKE-OFF ALTITUDE (95% RPM)
2. CLIMB ON COURSE TO 10,000 FT. WITH MILITARY THRUST
3. CRUISE AT AIRSPEED FOR MAXIMUM ENDURANCE UNTIL 10% OF INITIAL FUEL REMAINS.
4. 10% OF INITIAL FUEL IS ALLOWED FOR RESERVE AND LANDING.

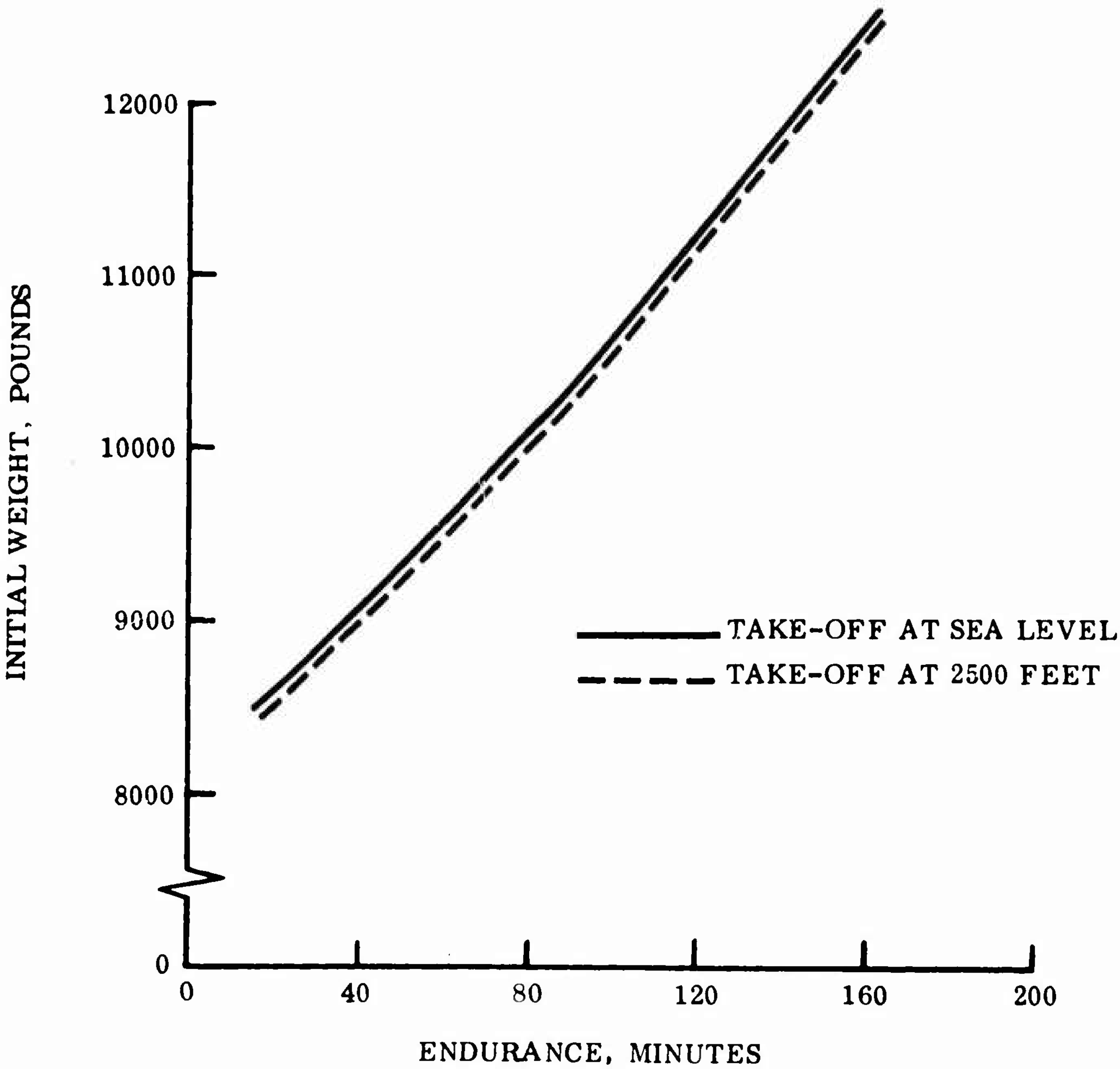

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Figure 10 Maximum Flight Endurance Versus Initial Weight

VELOCITY FOR MAXIMUM FLIGHT ENDURANCE VERSUS WEIGHT
CONVENTIONAL TAKE-OFF AND LANDING
CRUISE ALTITUDE - 10,000 FEET
TWO ENGINES OPERATING
ARDC STANDARD DAY

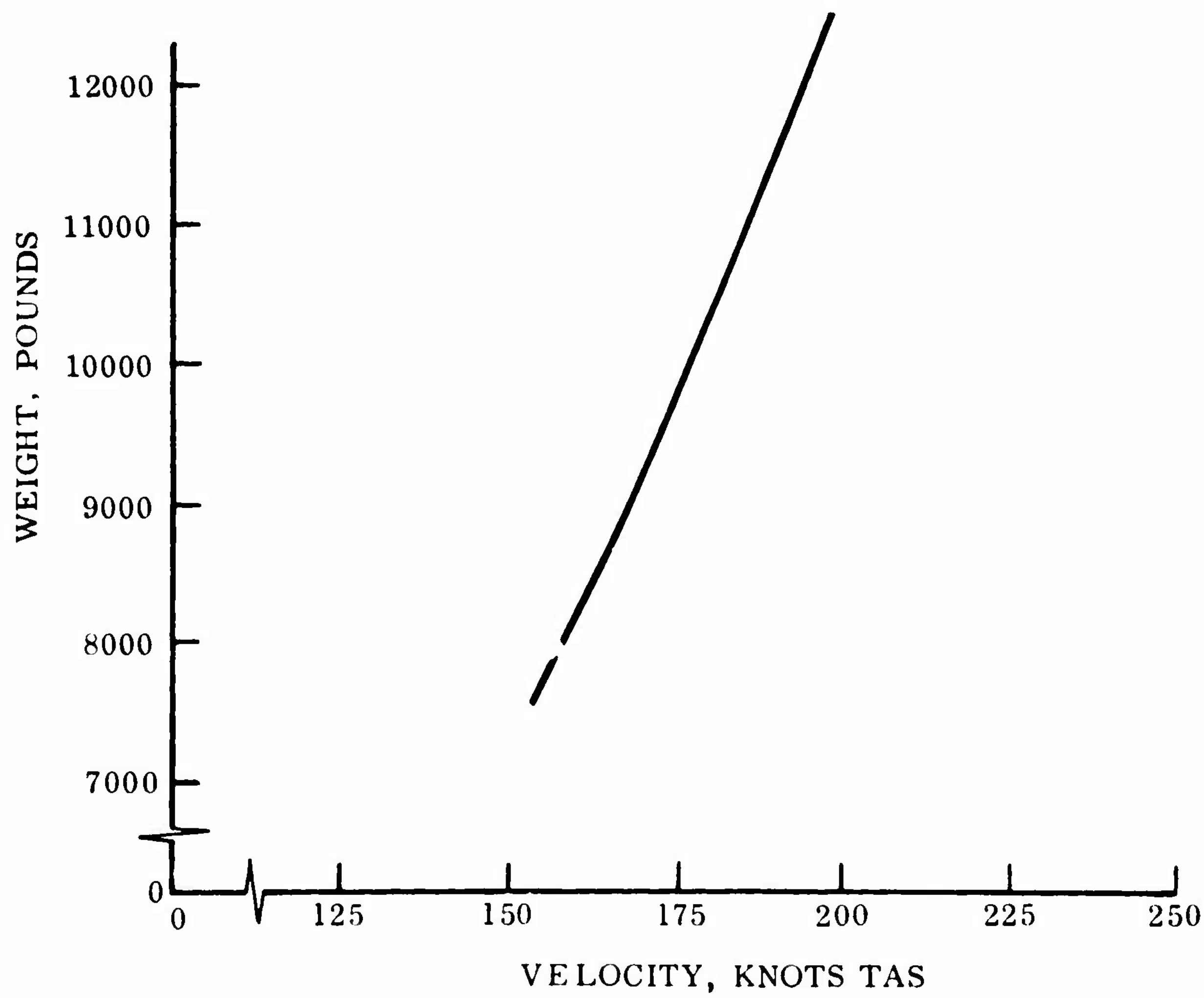

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Figure 11 Velocity for Maximum Flight Endurance Versus Weight

ALTITUDE VERSUS MAXIMUM RATE OF CLIMB
100% RPM OR TEMPERATURE LIMITED
ARDC STANDARD DAY

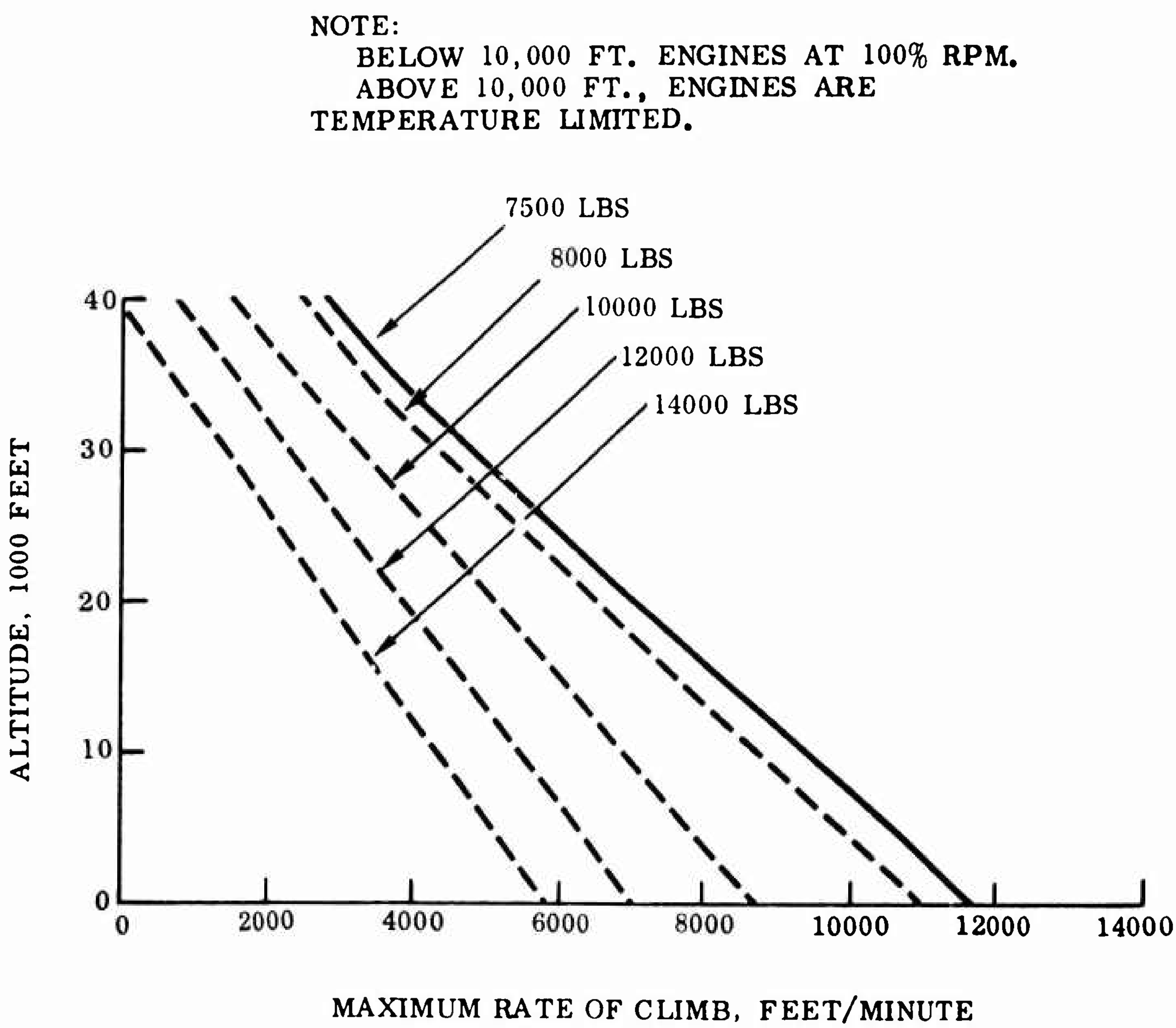

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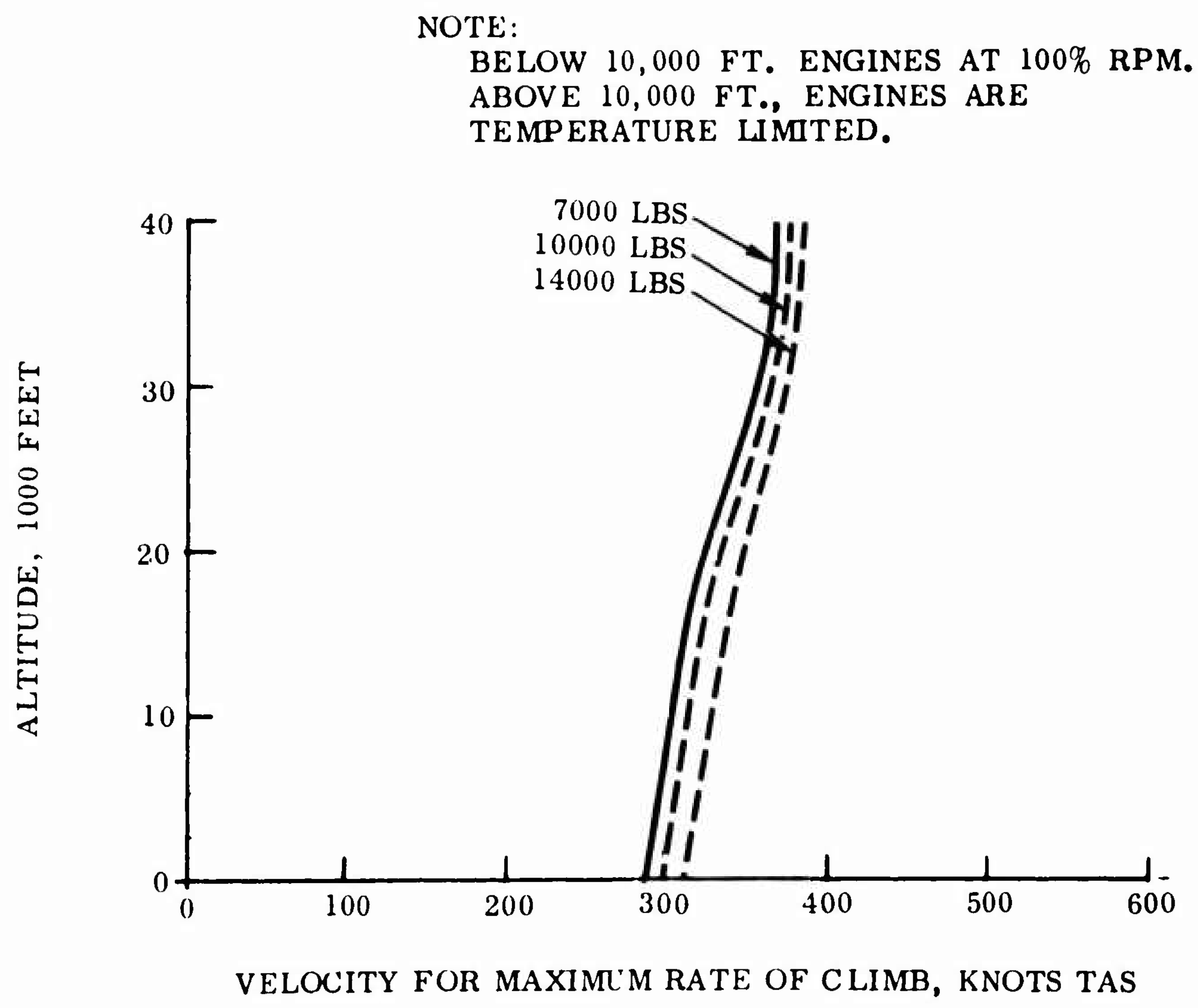
Figure 12 Altitude Versus Maximum Rate of Climb

ALTITUDE VERSUS VELOCITY FOR MAXIMUM RATE OF CLIMB
100% RPM OR TEMPERATURE LIMITED
ARDC STANDARD DAY



R-118-13 Figure 13 Altitude Versus Velocity for Maximum Rate of Climb

SPEED-ALTITUDE ENVELOPE
100% RPM OR TEMPERATURE LIMITED
ZERO RATE OF CLIMB
ARDC STANDARD DAY

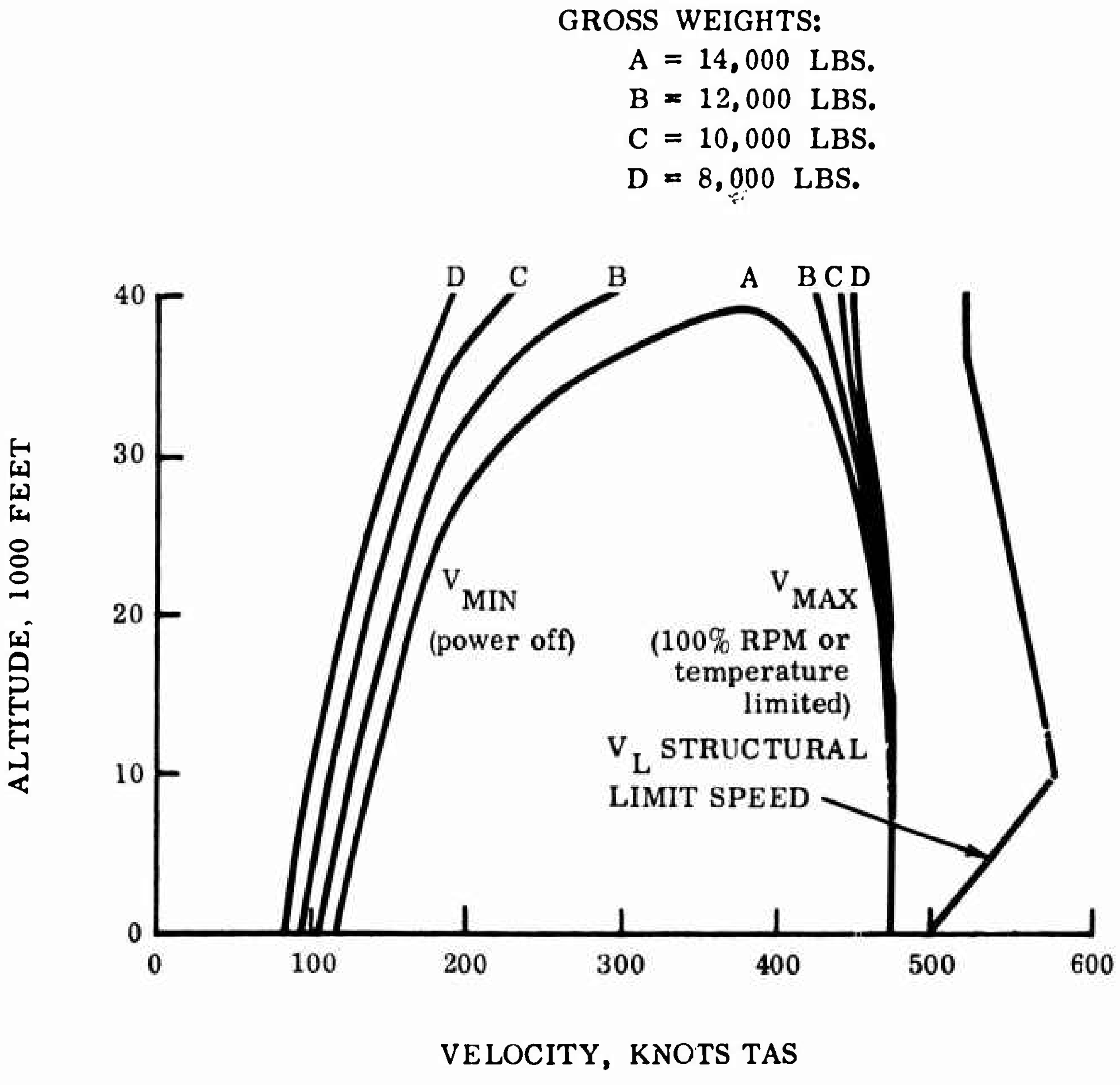


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Figure 14 Speed - Altitude Envelope

THRUST REQUIRED AND AVAILABLE VERSUS VELOCITY
SEA LEVEL ARDC STANDARD DAY

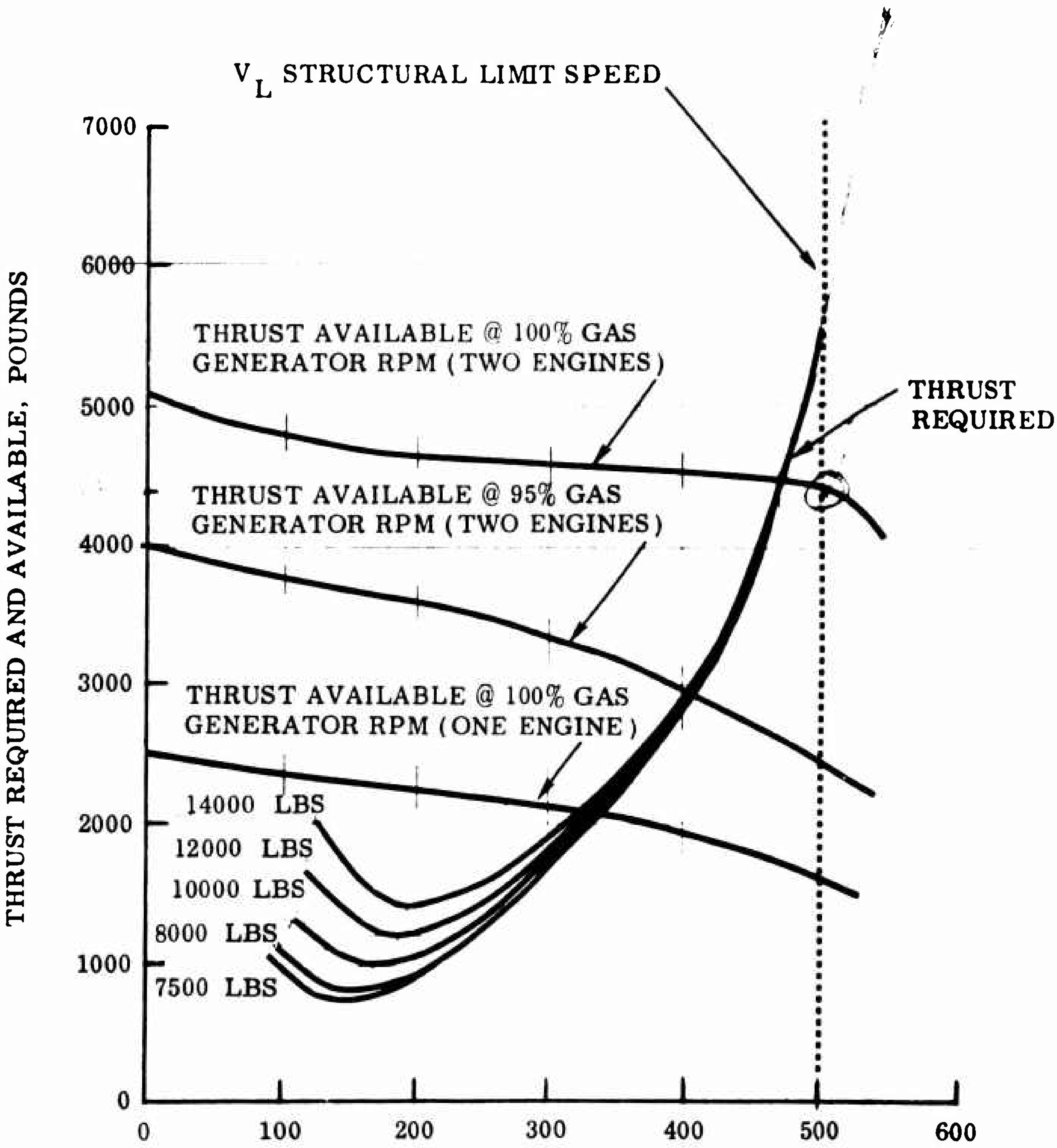

Figure 15 Thrust Required and Available Versus Velocity, Sea Level ARDC Standard Day

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THRUST REQUIRED AND AVAILABLE VERSUS VELOCITY
2500 FEET ARDC STANDARD DAY

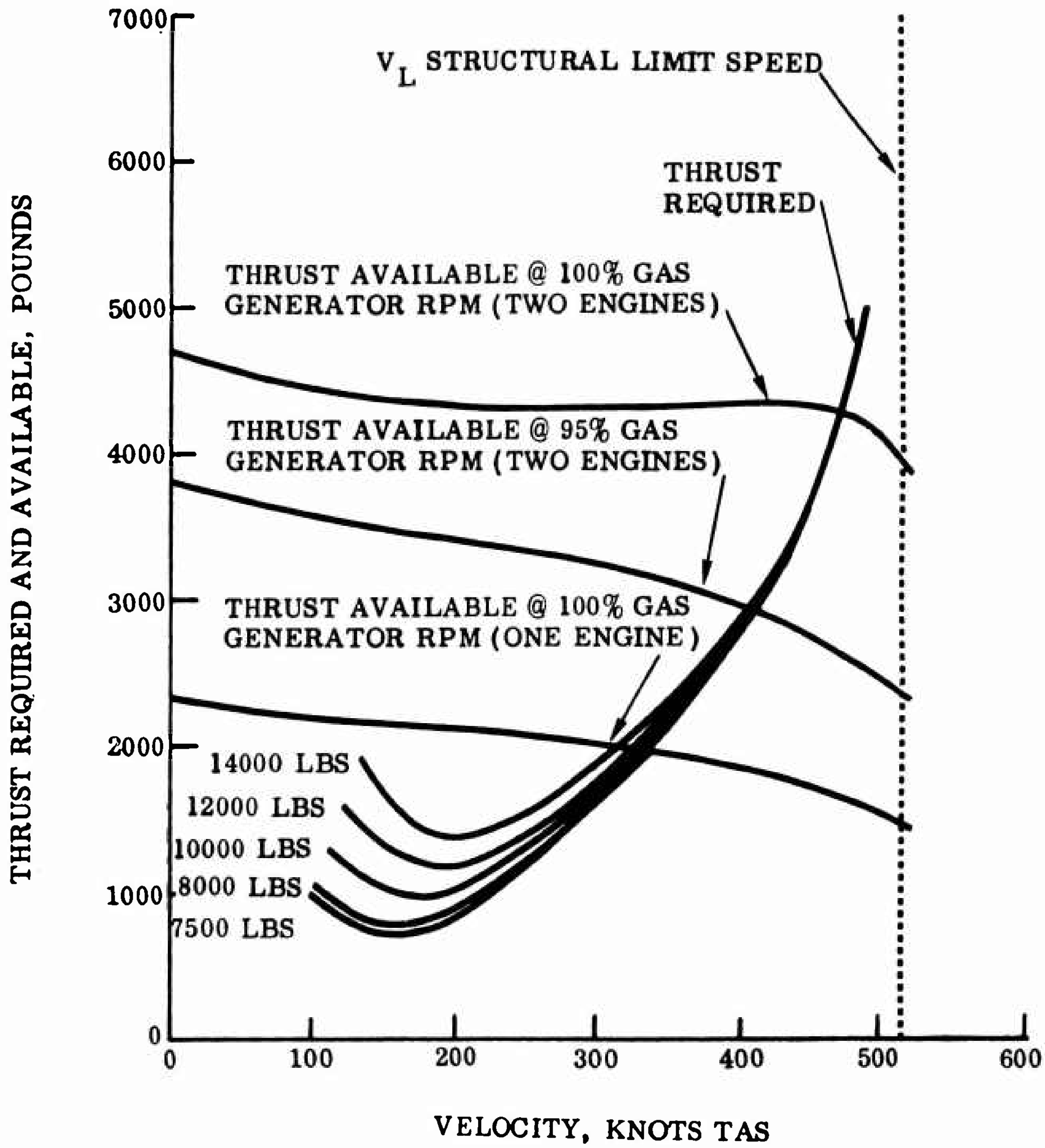

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Figure 16 Thrust Required and Available Versus Velocity,
2500 Feet ARDC Standard Day

THRUST REQUIRED AND AVAILABLE VERSUS VELOCITY
5000 FEET ARDC STANDARD DAY

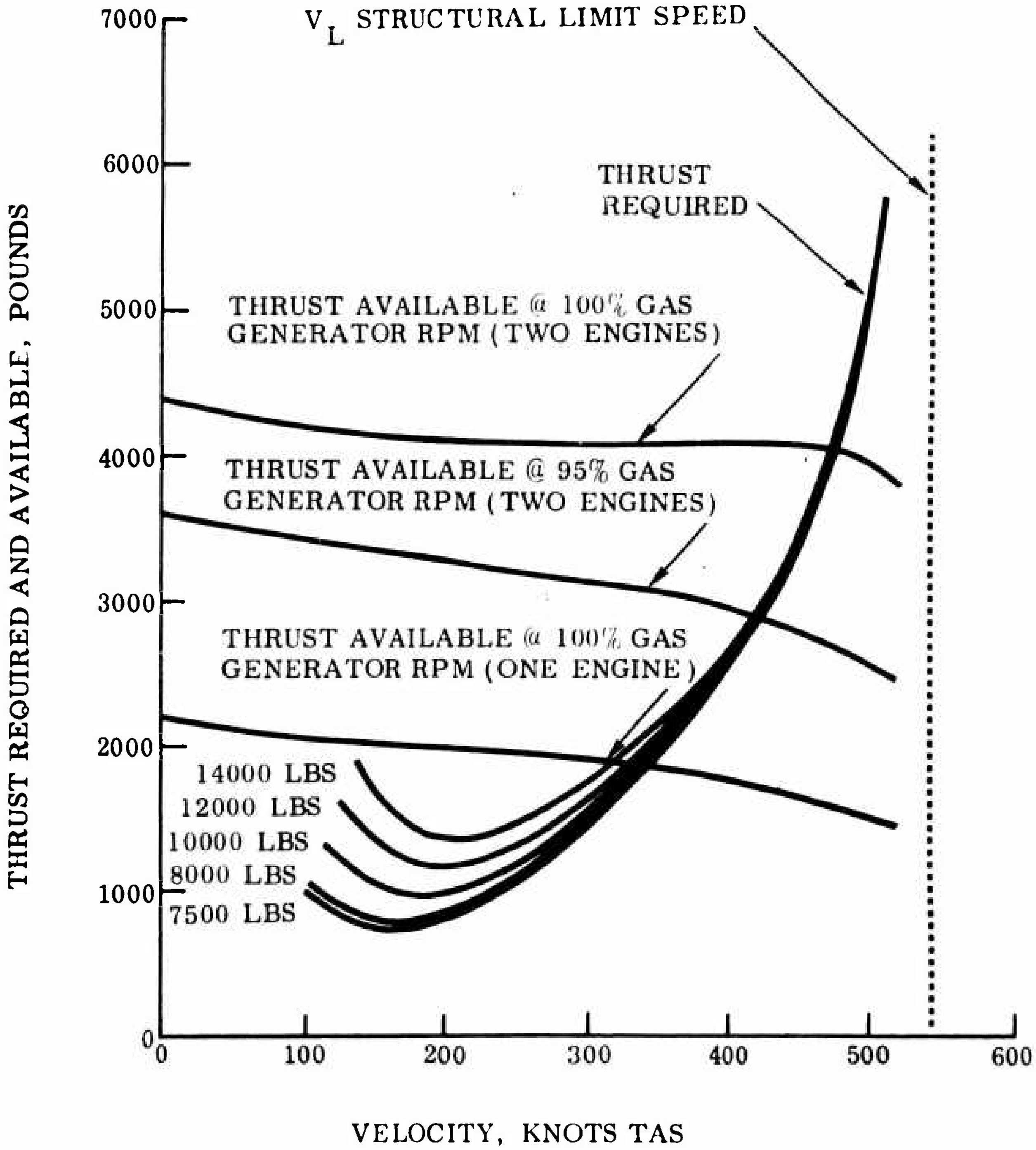

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Figure 17 Thrust Required and Available Versus Velocity, 5000 Feet ARDC Standard Day

THRUST REQUIRED AND AVAILABLE VERSUS VELOCITY
2500 FEET ANA 421 HOT DAY

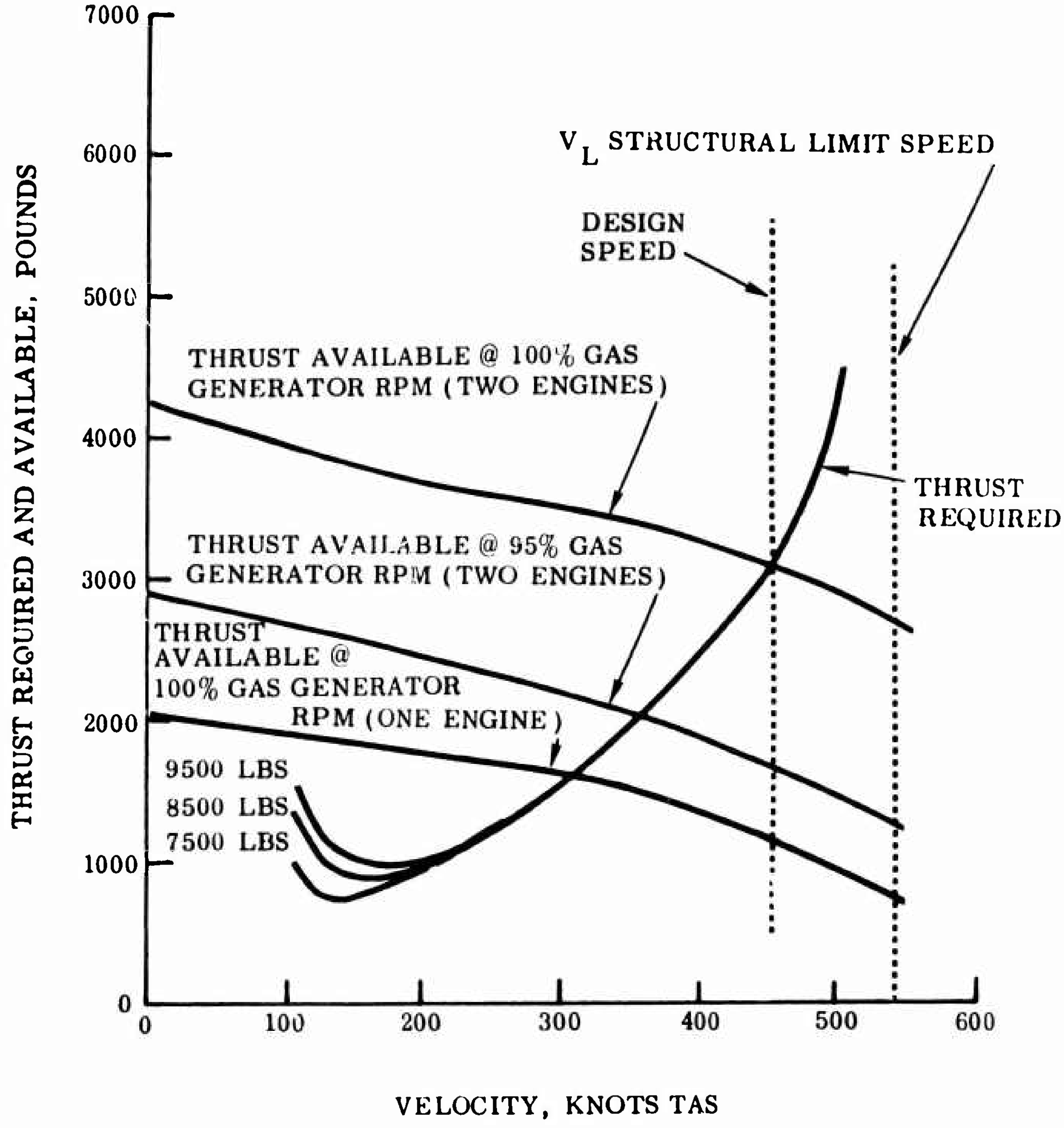


Figure 18 Thrust Required and Available Versus Velocity, 2500 Feet ANA 421 Hot Day

THRUST REQUIRED AND AVAILABLE VERSUS VELOCITY
5000 FEET ANA 421 HOT DAY

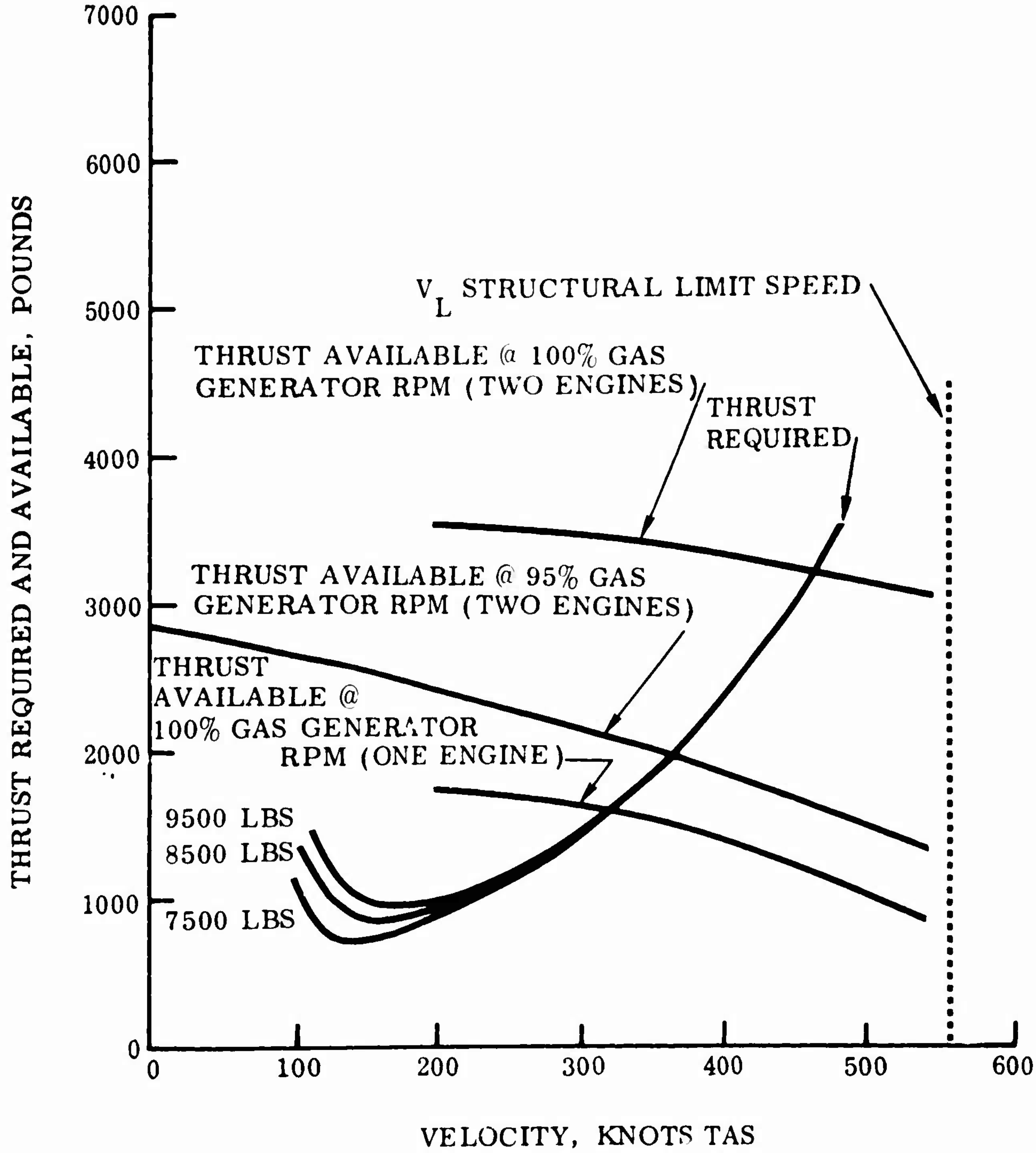
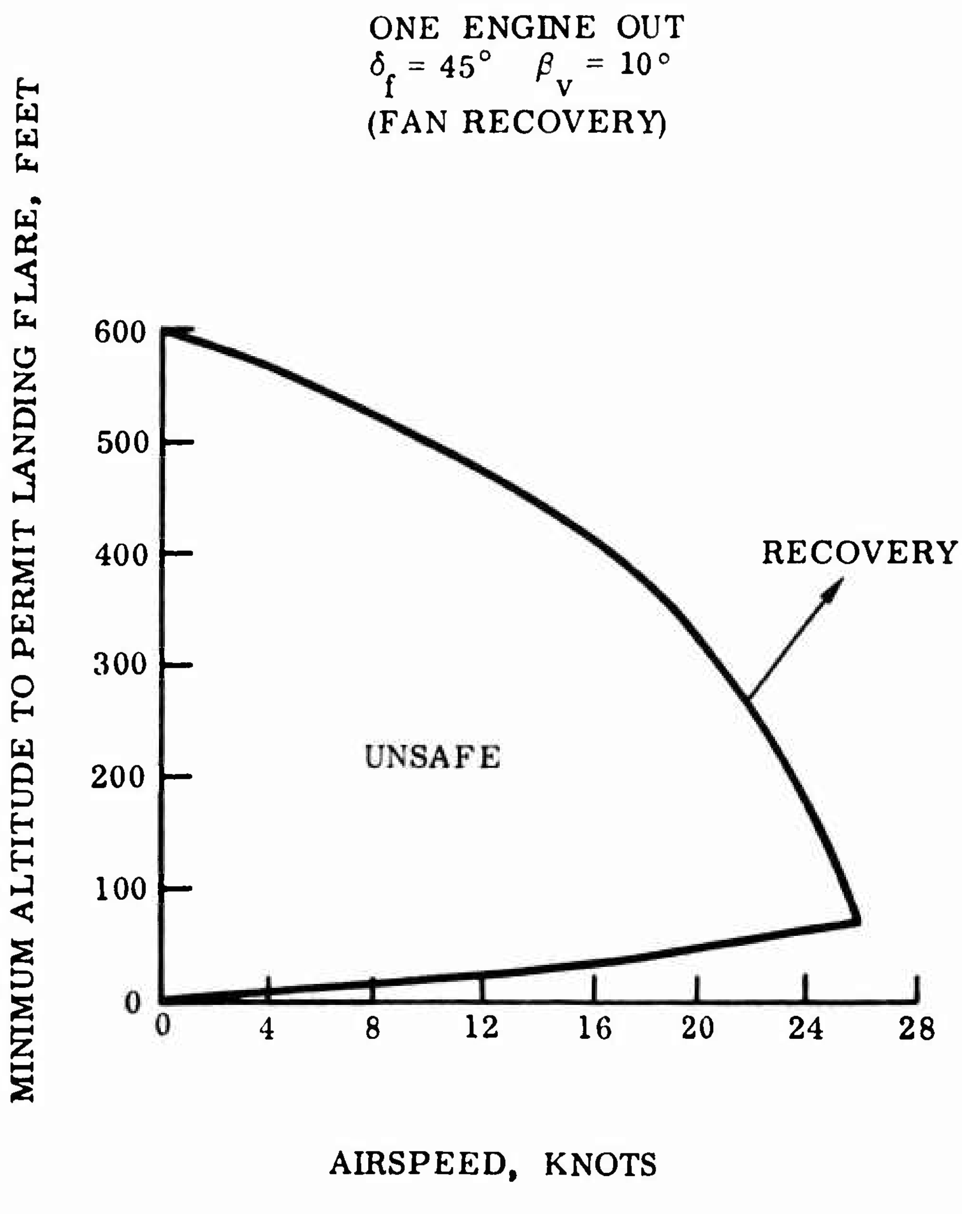


Figure 19 Thrust Required and Available Versus Velocity, 5000 Feet ANA 421 Hot Day
R-218-19

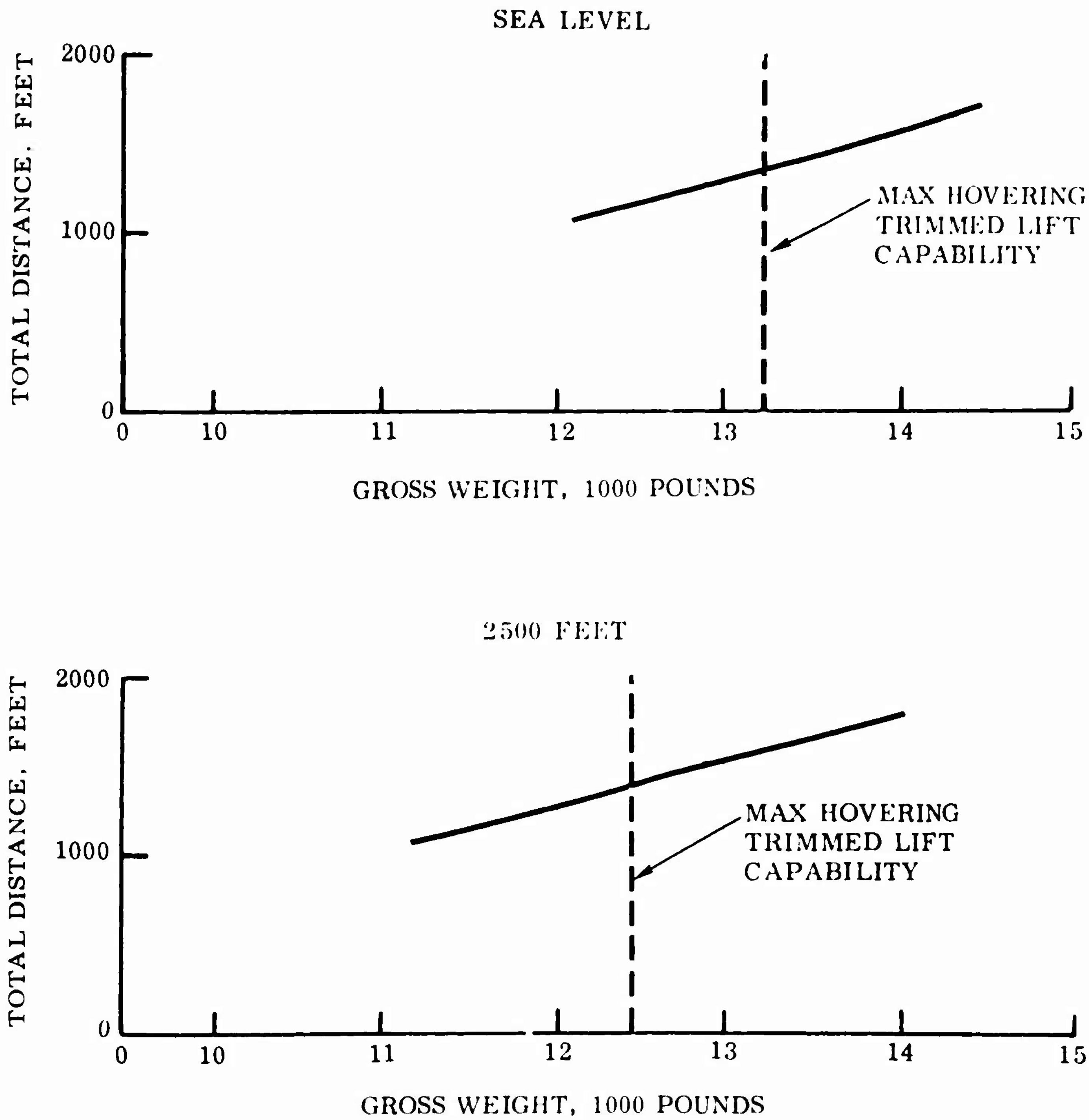
ESTIMATED FLIGHT RECOVERY ENVELOPE
SEA LEVEL ARDC STANDARD DAY
GROSS WEIGHT = 9200 POUNDS



R-218-20

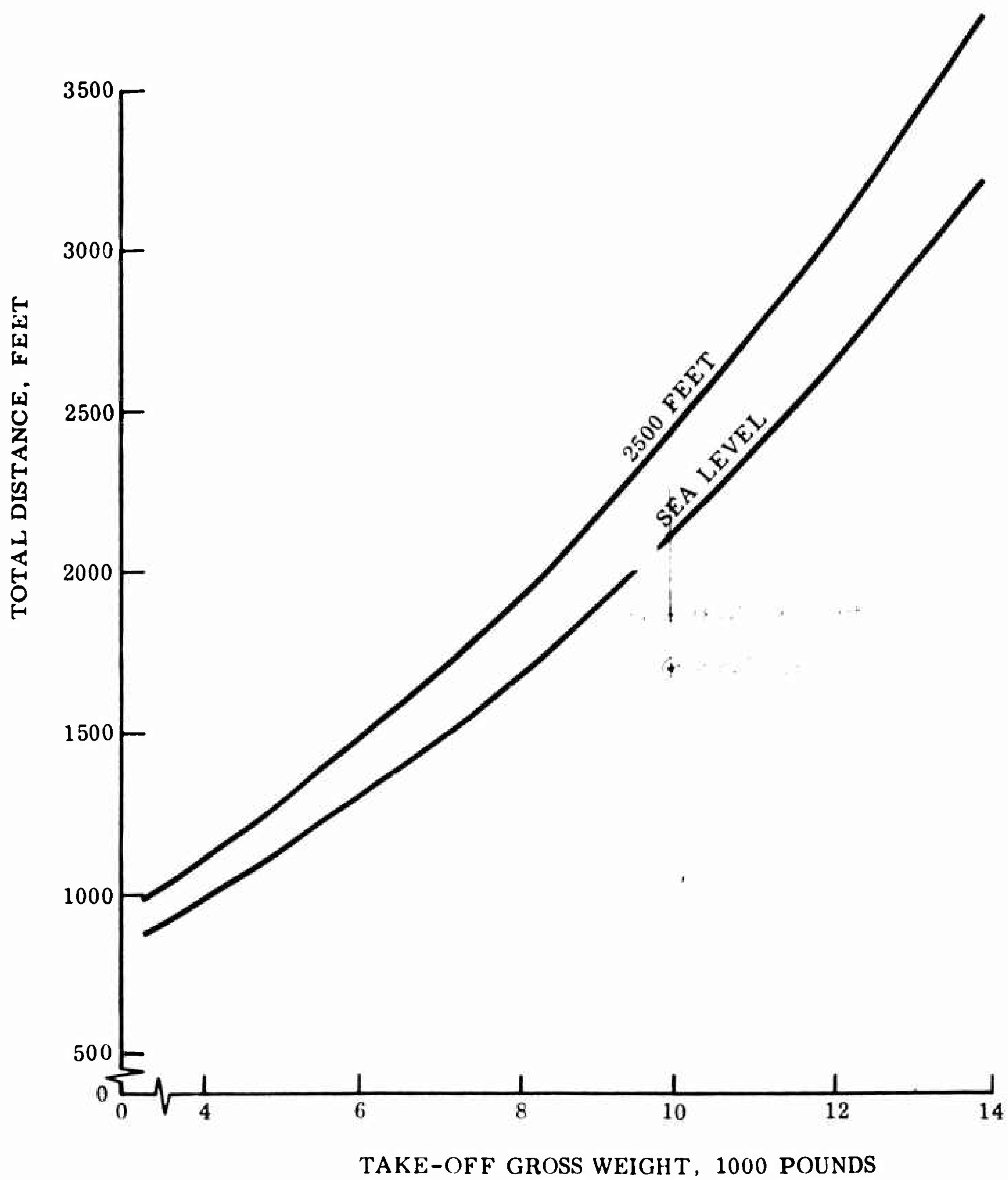
Figure 20 Estimated Flight Recovery Envelope

STOL TAKE-OFF DISTANCE OVER 50 FOOT OBSTACLE
ARDC STANDARD DAY
MILITARY POWER
$\delta_f = 45°$ $\beta_v = 40°$



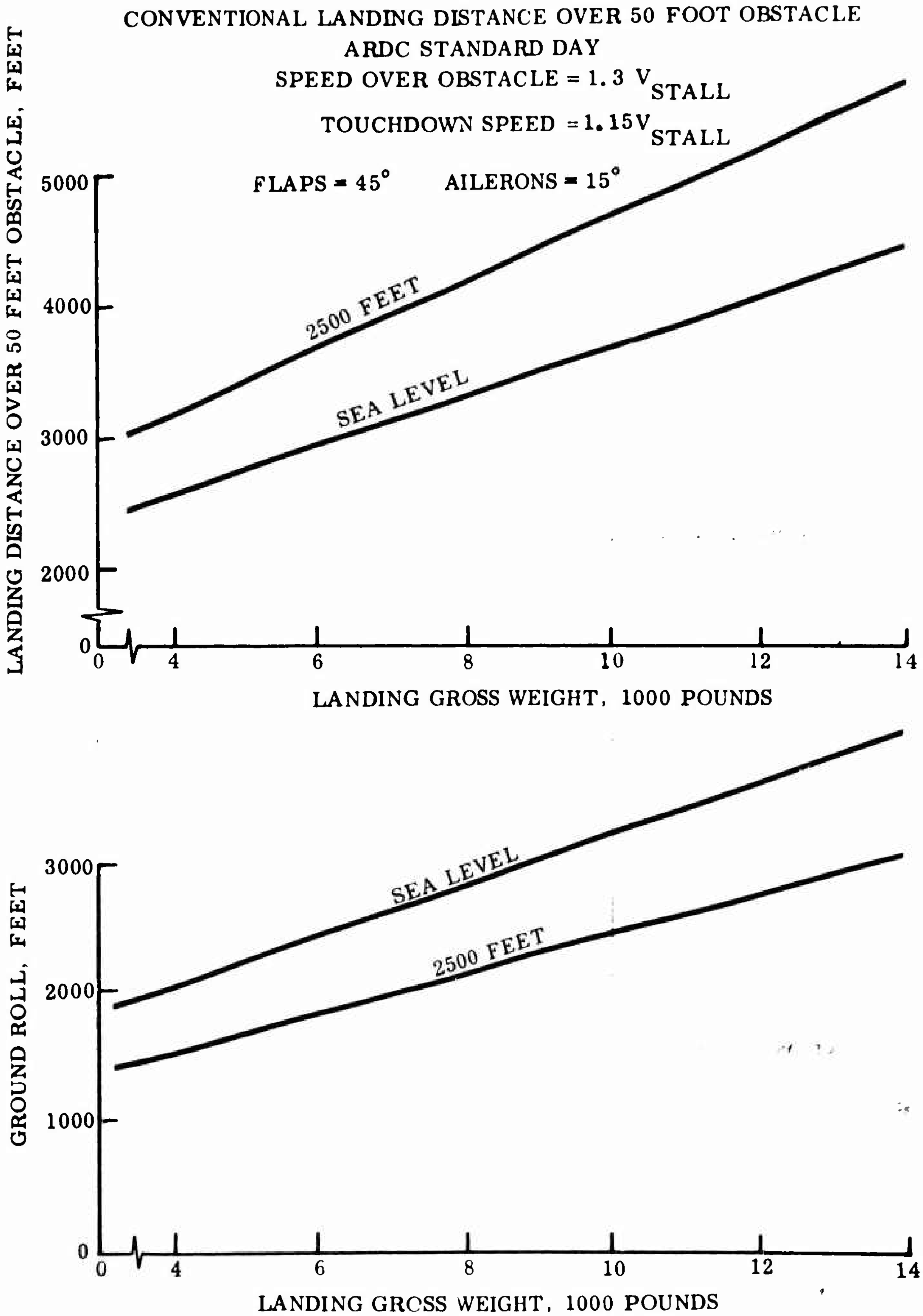
R-211-21 Figure 21 STOL Take-off Distance Over 50 Foot Obstacle

CONVENTIONAL TAKE-OFF DISTANCE OVER 50 FOOT OBSTACLE
ARDC STANDARD DAY
TAKE-OFF SPEED = 1.2 V_{STALL}
FLAPS = 30° AILERONS = 10°



R-218-22

Figure 22 Conventional Take-off Distance Over 50 Foot Obstacle

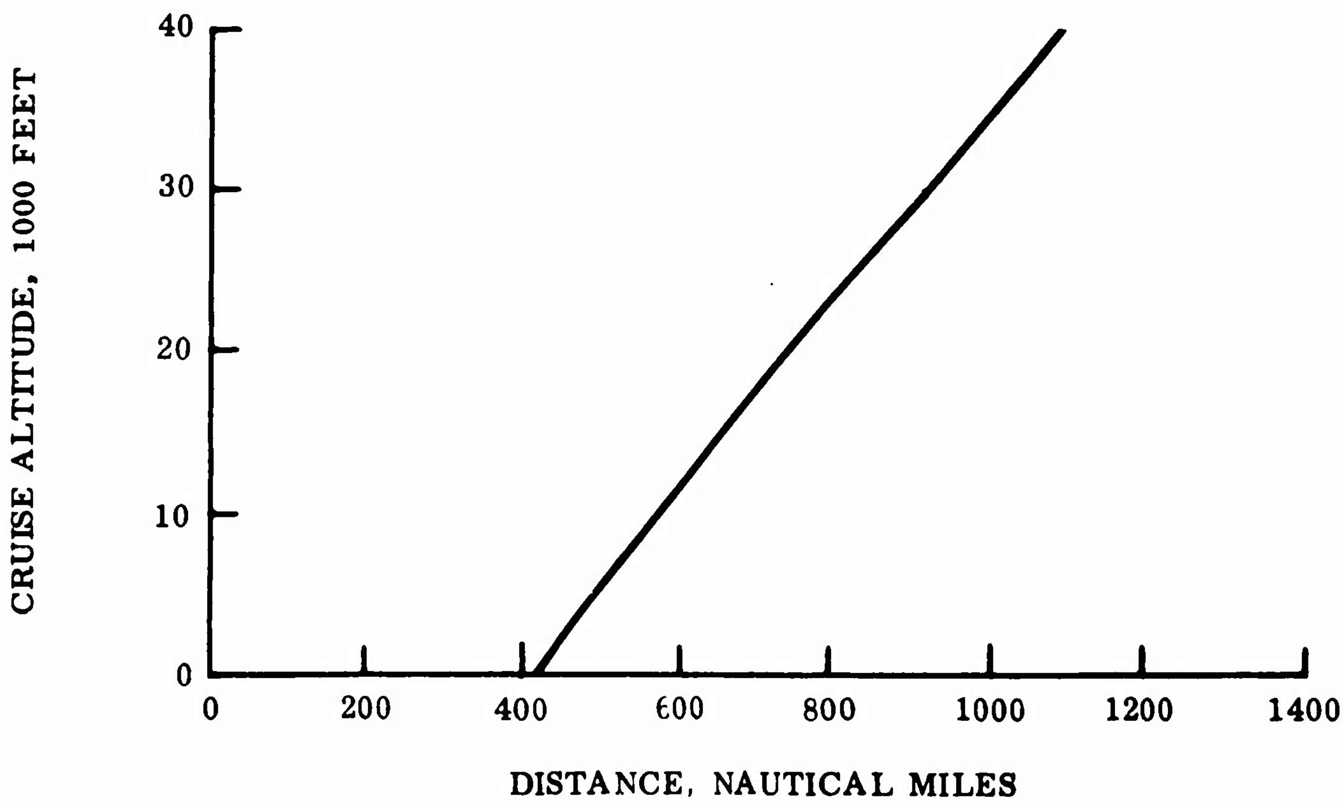


R-218-23 Figure 23 Conventional Landing Distance Over 50 Foot Obstacle

FERRY DISTANCE
ARDC STANDARD DAY
CONVENTIONAL TAKE-OFF FROM SEA LEVEL

NOTES:

1. TAKE-OFF WEIGHT 12,684 POUNDS
2. TOTAL INTERNAL FUEL 4650 POUNDS. 4600 POUNDS USABLE
3. FUEL ALLOWANCE FOR STARTING ENGINES, TAKE-OFF, AND ACCELERATE-TO-CLIMB SPEED IS POUNDS OF FUEL USED IN 5.0 MINUTES WITH NORMAL POWER AT SEA LEVEL (95% RPM)
4. CLIMB ON COURSE TO CRUISE ALTITUDE WITH MILITARY THRUST
5. CRUISE AT AIRSPEED FOR MAXIMUM RANGE UNTIL 10% OF INITIAL USABLE FUEL REMAINS
6. FUEL ALLOWANCE FOR RESERVE AND LANDING IS 10% OF INITIAL USABLE FUEL



R-218-24

Figure 24 Ferry Distance

9103-C-?AB

GROUP WEIGHT STATEMENT
WEIGHT EMPTY

1	WING GROUP						
2	CENTER SECTION-BASIC STRUCTURE						
3	INTERMEDIATE PANEL-BASIC STRUCTURE						
4	OUTER PANEL-BASIC STRUCTURE - INCL TIPS				LBS	152	
5							
6	SECONDARY STRUCTURE - INCL WINGFOLD MECH				LBS	296	
7	AILERONS - INCL BALANCE WEIGHT			LBS			
8	FLAPS-TRAILING EDGE						
9	-LEADING EDGE						
10	SLATS						
11	SPOILERS						
12	SPEEDBRAKES						
13							
14							
15	GROUP						
16	STABILIZER-BASIC STRUCTURE						
17	FINS-BASIC STRUCTURE-INCL DORSAL			LBS			
18	SECONDARY STRUCTURE-STABILIZER & FINS						
19	ELEVATOR - INCL BALANCE WEIGHT			LBS			
20	RUDDERS - INCL BALANCE WEIGHT			LBS			
21							
22							
23	GROUP						
24	FUSELAGE OR HULL-BASIC STRUCTURE						
25	BOOMS-BASIC STRUCTURE						
26	SECONDARY STRUCTURE-FUSELAGE OR HULL						
27	-BOOMS						
28	-SPEEDBRAKES						
29	-DOORS, PANELS & MISC					247	
30							
31	ALIGHTING GEAR GROUP-LAND - TYPE						
32	LOCATION	*ROLLING ASSEMBLY	STRUCT	CONTROLS			
33							
34	NOSE	23	33	13			
35	MAIN	90	201	46			
36							
37							
38							
39	ALIGHTING GEAR GROUP-WATER						
40	LOCATION	FLOATS	STRUTS	CONTROLS			
41							
42							
43							
44							
45	SURFACE CONTROLS GROUP						
46	COCKPIT CONTROLS						
47	AUTOMATIC PILOT						
48	SYSTEM CONTROLS - INCL POWER & FEEL CONT				LBS		
49	TAKE-OFF AND LANDING CONTROLS						
50	ENGINE SECTION OR NACELLE GROUP						
51	INBOARD						
52	CENTER						
53	OUTBOARD						
54	DOORS, PANELS & MISC						
55							
56	SPACE TOTAL						
57							

* WHEELS, BRAKES, TIRES, TUBES AND AIR

GROUP WEIGHT STATEMENT
WEIGHT EMPTY

G.E.
Ryan

	LIFT FAN	NOSE FAN		
1 PROPULSION GROUP	X	AUXILIARY XX	MAIN	X
2				
3 ENGINE INSTALLATION + DIVERTER VALVE	1594	113	934	
4 AFTERBURNERS-IF FURN SEPARATELY				
5 ACCESSORY GEAR BOXES & DRIVES			30	
6 SUPERCHARGER FOR TURBO TYPES				
7 AIR INDUCTION SYSTEM	153	182	26	
8 EXHAUST SYSTEM		67	230	
9 COOLING SYSTEM				
10 SPLITTER DUCTS, ETC.				
11 TANKS				
12 COOLING INSTALLATION				
13 DUCTS, PLUMBING, ETC				
14 FUEL SYSTEM				
15 TANKS-PROTECTED				
16 -UNPROTECTED			68	
17 PLUMBING, ETC			36	
18 WATER INJECTION SYSTEM				
19 ENGINE CONTROLS			28	
20 STARTING SYSTEM			7	
21 LIFT FAN				
22 FAN MOUNTING				
23 PITCH FAN	8	3		
24 AUXILIARY POWER PLANT GROUP				
25 INSTRUMENTS & NAVIGATIONAL EQUIPMENT GROUP				
26 HYDRAULIC & PNEUMATIC GROUP				
27				
28				
29 ELECTRICAL GROUP				
30 AC SYSTEM				
31 DC SYSTEM				
32 ELECTRONICS GROUP ARC51X RADIO				
33 EQUIPMENT				
34 INSTALLATION				
35				
36 ARMAMENT GROUP - INCL GUNFIRE PROTECTION			LBS	
37 FURNISHINGS & EQUIPMENT GROUP				
38 ACCOMMODATIONS FOR PERSONNEL (IN-2 SEAT)				
39 MISCELLANEOUS EQUIPMENT				
40 FURNISHINGS				
41 EMERGENCY EQUIPMENT				
42				
43 AIR CONDITIONING & ANTI-ICING EQUIPMENT GROUP				
44 AIR CONDITIONING				
45 ANTI-ICING				
46				
47 PHOTOGRAPHIC GROUP				
48 AUXILIARY GEAR GROUP				
49 HANDLING GEAR				
50 ARRESTING GEAR				
51 CATAPULTING GEAR				
52 ATO GEAR				
53 SPIN CHUTE				
54 MANUFACTURING VARIATION				
55				
56 PAGE TOTAL				
57 TOTAL-WEIGHT EMPTY -				

GROUP WEIGHT STATEMENT
USEFUL LOAD & GROSS WEIGHT

1	LOAD CONDITION			DESIGN		
2						
3	CREW - NO. (1)			200		
4	PASSENGERS - NO.					
5	FUEL	TYPE	GALS			
6	UNUSABLE	JP-4		45		
7	INTERNAL Tank	JP-4		1121		
8						
9						
10	EXTERNAL					
11						
12	BOMB BAY					
13						
14	OIL					
15	TRAPPED	2 Qts.		3		
16	ENGINE	7 Qts.		12		
17						
18	FUEL TANKS-LOCATION					
19	WATER INJECT. FLUID(		GALS)			
20						
21	BAGGAGE					
22	CARGO					
23						
24	ARMAMENT					
25	GUNS-LOCATION FIX/FLEX	QUANTITY	CALIBER			
26						
27						
28						
29						
30						
31						
32	AMMUNITION					
33						
34						
35						
36						
37						
38						
39	INSTALLATIONS-BOMB, TORPEDO, ROCKET, ETC					
40*	BOMB OR TORPEDO RACKS					
41						
42						
43	INSTRUMENTATION			300		
44						
45						
46	EQUIPMENT					
47	PYROTECHNICS					
48	PHOTOGRAPHIC					
49						
50*	OXYGEN					
51						
52	MISCELLANEOUS					
53						
54						
55	USEFUL LOAD			1681		
56	WEIGHT EMPTY			7519		
57	GROSS WEIGHT			9200		

3.1.4 Center of Gravity Locations. -

Design gross weight (basic flight): 9200 pounds.

Aft LE of MAC 26.4 percent MAC.

Above LE of MAC 8.4 inches.

Most forward center of gravity possible in flight at gross weight of 9200 pounds.

Aft LE of MAC 25.6 percent.

Above LE of MAC 6.9 inches.

Most rearward center of gravity possible in flight at gross weight of 7614 pounds.

Aft LE of MAC 30.9 percent.

Above LE of MAC 8.5 inches.

3.1.5 Areas. - (This information is not to be used for inspection purposes).

Wing area total theoretical including ailerons, flaps and projection to aircraft plane of symmetry (49 square feet of fuselage).	260.321 square feet
Wing flap area, aft of hinge line, total.	25.368 square feet
Aileron area, aft of hing line, including 2.75 square feet of tab area.	20.114 square feet
Horizontal tail area, total.	52.864 square feet
Elevator, aft of hinge line, per side.	5.985 square feet
Vertical Tail area, total.	50.995 square feet
Fin, not including rudder area aft of rudder hinge line.	44.600 square feet
Rudder, aft of hinge line, including 0.714 square feet of tab area.	6.395 square feet

3.1.6 Dimensions and General Data. - (This information is not to be used for inspection purposes.)

Wings:

Span:	29.833 feet

Chord:

At root.	145.000 inches
At break of quarter chord line.	109.005 inches
At construction tip (theoretical extended section at tip).	43.000 inches
Mean aerodynamic.	112.919 inches
LE mean aerodynamic (fuselage station).	211.140

Airfoil Section:

Butt line 170.05, NACA 0012-64,
a=0.8(modified), $C_{l_i} = 0.2$

Airfoil Maximum Thickness:

At root (BL 24.00) 10.55 percent
At fan center line (BL 61.00) 11.84 percent
At quarter chord break (BL 100.75) 13.36 percent
At tip (BL 170.05) 12.00 percent

Incidence:

Butt line 24.00 (approximately wing-fuselage intersection).	-0.110 degrees
Butt line 170.05 (95 percent semi-span)	-3.00 degrees

Sweepback at 25 percent chord:

Inboard panel.	15.000 degrees
Outboard panel.	28.343 degrees

Dihedral:

Inboard panel.	0.00 degrees
Outboard panel (from BL 107.00).	4.00 degrees

Aspect Ratio:	3.419

Ailerons:

Span.	75.50 inches
Chord. (average percent wing chord).	29.63 percent
Tab (both wings), span.	39.86 inches
Tab (both wings), chord, average.	4.97 inches
Distance from plane of symmetry to centroid of aileron area.	139.61 inches
Amount of aerodynamic balance (average, excluding seal).	22.30 percent chord

Flaps:

Type: single slotted.	
Span (percent of wing).	43.0 percent
Chord (average percent of wing).	19.6 percent

Tail:

Horizontal:

Span.	13.183 feet
Root chord.	65.64 inches
Tip chord.	30.60 inches
Airfoil section NACA 64A012.	
Incidence (variable) 20 degrees up, 5 degrees down.	
Sweep of LE	19.519 degrees
Dihedral.	0.0 degrees
Aspect Ratio.	3.288

Elevators:

Span, per side.	5.471 feet
Root chord (BL 4.26).	16.033 inches
Tip chord. (BL 69.91).	10.224 inches
Balance. -- Internally sealed pressure balance	
Aerodynamic balance. (excluding seal).	19.4 percent

Vertical:

Airfoil section:	
Water line 113.00 inches NACA 64A(012) - 016.5	
Tip (water line 206.00 inches) NACA 64A(012) - 013	
Sweep of leading edge.	35.435 degrees
Aspect Ratio.	1.178
Tab:	
Span.	24.96 inches
Chord. (MAC)	4.128 inches
Aerodynamic balance (excluding seal).	25.4 percent

Height over highest point of vertical tail, reference line level.	14.75	feet
Height in hoisting attitude, from top of hoist sling to lowest part of aircraft.	15.0	feet
Length (reference line level).	44.52	feet
Length from hoisting sling to farthest aft point.	23.0	feet
Distance from wing MAC quarter chord point to horizontal tail MAC quarter chord point.	21.17	feet
Distance from wing MAC quarter chord point to vertical tail MAC quarter chord point.	18.25	feet
Angle between reference line and wing zero-lift line.	-1.50	degrees
Rotation ground clearance	21.0	degrees
Wheel and tire size:		
Main wheels.	20 x 4.4	
Nose wheel.	18 x 4.4	
Tread of main wheels (static standing)	100.7 @ 9200 lbs. G. W.	inches
Wheel base: Normal.	140.4 @ 9200 lbs. G. W.	inches
VTOL.	160.4 @ 9200 lbs. G. W.	inches

Vertical travel of axles from fully extended to fully compressed:		
Main wheels.	9.0	inches
Nose wheel.	8.0	inches
Distance from main wheel contact point to center of gravity (VTOL position):		
Horizontal distance:		
At most forward CG station 240.0 inches at 9200 pounds gross weight	56.0	inches
At most aft CG station 246.0 inches at 8481 pounds gross weight.	50.00	inches
Vertical distance:		
At most forward CG water line 113.6 inches at 9200 pounds gross weight.	80.6	inches
At most aft CG water line 114.0 inches at 8481 pounds gross weight.	81.0	inches
Distance from main wheel contact point to center of gravity (conventional position):		
Horizontal distance:		
At most forward CG station 240.0 inches at 9200 pounds gross weight.	36.00	inches
At most aft CG station 246.0 inches at 8481 pounds gross weight.	30.00	inches
Vertical distance:		
At most forward CG water line 113.6 inches at 9200 pounds gross weight.	80.6	inches
At most aft CG water line 114.0 inches at 8481 pounds gross weight.	81.0	inches

3.1.7 Control Movement and Corresponding Control Surface Movements. - (The following deflections are variable, and only their maximum limits are shown. This information is not to be used for inspection purposes.)

Rudder 25 degrees right, 25 degrees left.
Rudder pedals 3.25 inches forward, 3.25 inches aft.
Rudder tab 10 degrees right, 10 degrees left.
Elevator 25 degrees above, 25 degrees below.
Elevator control 6 inches aft, 6 inches forward.
Ailerons 19 degrees above, 15 degrees below (flaps at 0°).
Aile ns 23 degrees above, 12 degrees below (droop at 15°).
Aileron control stick 5 inches right, 5 inches left.
Aileron tab right side 27.14 degrees above, 17.70 degrees below.
Aileron tab left side 30.14 degrees above, 20.70 degrees below.
Stabilizer 20 degrees L.E. up, 5 degrees L.E. down.
Wing flap 45 degrees maximum movement down.
Nose fan thrust control door deflection (from maximum lift condition) 68 degrees.
Wing fan louver yaw control ($\beta_{V_{left}} - \beta_{V_{right}}$ total differential vector at nominal collective lift condition $\beta_S = 27°$ with $\beta_V = 0°$) 32 degrees.
Wing fan louver roll control ($\beta_{S_{right}} - \beta_{S_{left}}$ total differential stagger at nominal collective lift condition $\beta_S = 27°$ with $\beta_V = 0°$) 24 degrees.
Collective louver stagger angle (β_S) at $\beta_V = 0°$, minus 13 degrees to plus 37 degrees.
Collective louver vector angle (β_V) minus 5 degrees to plus 50 degrees.

3.2 General Features of Design and Construction. -

3.2.1 General Interior Arrangement. - Refer to Figure 2. The forward fuselage shall contain the nose fan, pilot's compartment, and nose gear. A nose fairing shall be provided forward of the cockpit and shall contain the pitot mast. The nose fan shall be located directly aft of the fairing and shall be provided with inlet louver closures. Thrust control doors shall be used to modulate fan lift, and shall be installed below the nose fan. The cockpit shall utilize side-by-side seating with the pilot located on the left-hand side of the cockpit. Provisions shall be made for installation of a passenger-observer seat, or data acquisition equipment, on the right-hand side of the cockpit. All primary flight controls shall be routed beneath the cockpit floor. The forward folding nose gear shall be located directly beneath the cockpit.

3.2.1.1 The center fuselage bay shall contain the avionics group, gas producers, diverter valves, cross ducts, nose-fan bleed ducts, and one fuel tank. The avionics group shall be installed in a compartment located directly behind the cockpit bulkhead, and shall consist of the auto-stabilization system and electrical system equipment. The

forward main fuel tank shall be located directly behind the avionics compartment and shall be an integral type tank with bladder sealing. Engine accessory drive equipment shall be located above the avionics compartment. A separate hydraulic pump, generator, and mechanically driven fan system shall be installed on each side of the aircraft, with each system driven by a separate gas producer. Gas producers and diverter valves shall be located in the top portion of the center fuselage bay and shall be coupled to the cross-over ducts and conventional-flight tailpipes. A compartment shall be provided immediately below the forward main fuel tank, which may be used for equipment. Nose fan gas distribution ducts shall be located in the center fuselage bay immediately inboard of the fuselage skin. Flight controls shall be routed from the center fuselage bay outboard to the wings.

3.2.1.2 The aft fuselage bay shall contain the aft main fuel tank, extended range dorsal fuel tank, engine tailpipes, main landing gear, and thrust spoiler system. The aft main fuel tank shall be located beneath the engine tailpipe shrouds, and behind the cross-over ducts. Conventional-flight tailpipes shall be routed from the aft end of the diverter valves, to the aft fuselage lower section. Tailpipe expansion features shall be provided by a bellows-type flexible joint which couples the diverter valves and tailpipe assemblies. The main landing gear shall be located beneath the aft main fuel tank and shall provide for two positions: forward for CTOL and STOL; aft for VTOL. A thrust spoiler system shall be located directly behind the tailpipe nozzles. An anti-spin and drag chute compartment shall be located in the aft portion of the fuselage.

3.2.2 Selection of Materials. - ANA Bulletin 143 and other applicable design documents shall be used as a guide in selection and use of materials.

3.2.3 Workmanship. - Workmanship shall be in accordance with highest standard aircraft practices. Special attention shall be given to maximum smoothness and accuracy of exterior surfaces.

3.2.4 Production, Maintenance, and Repair. - Design of the aircraft shall provide for ease of manufacture and maintenance throughout the expected service life. Power plants, fan assemblies, and equipment installations shall be readily removable. The wing, elevators, horizontal stabilizer, ailerons, flaps, and landing gears shall be readily removable. Requirements for special tools shall be held to a minimum.

3.2.5 Interchangeability and Replaceability. - Major assemblies such as wings, tail surfaces, and control surfaces shall be readily replaceable at their attach points.

3.2.6 Finish. - Aircraft components shall be protected from corrosion, and finished in accordance with Ryan finish specification 14359-1 dated 5 July 1962. Exterior aircraft surface shall be polished and unpainted with exception of materials subject to corrosion. Interior of the aircraft shall be finished to insure protection throughout the intended service life of the aircraft.

3.2.7 Identification and Marking. - Aircraft identification and marking shall be in accordance with Specification MIL-P-11747, with exception of deviations required due to unique features of the aircraft.

3.2.8 Extreme Temperature Operation. - The aircraft shall be designed to operate satisfactorily within a temperature environment of minus 40° F and plus 135° F.

3.2.9 Climatic Requirements. - Since the aircraft is primarily a flight research vehicle, there shall be no provision for climatic requirements other than those listed in paragraph 3.2.8 above.

3.2.10 Lubrication. - Lubrication shall conform to the requirements of Specification MIL-L-6880B.

3.2.11 Equipment and Furnishing Installation. - Equipment and furnishings shall be provided and installed, as described in applicable portions of this specification.

3.2.12 Crew. - The crew shall consist of 1 pilot. Provisions shall be made for accommodation of a second crew member located on the right-hand side of the cockpit. The pilot shall have all operational control authority. The second crew member shall be a passenger or observer only.

3.2.13 Noise and Vibration Requirements. - The aircraft and equipment shall function normally in all extremes of noise and vibration encountered in hovering, transition, and forward flight.

3.2.13.1 Vibration. - The aircraft shall be designed to insure against the possibility of catastrophic fatigue failures occurring within the design life of the aircraft.

3.2.13.2 Crew Comfort. -

3.2.13.2.1 Acoustical Noise. - Insofar as practicable, acoustical noise shall not exceed limits stated in specification MIL-A-8806(ASG).

3.2.13.2.2 Vibration. - Vibration of crew seats, rudder pedals, control columns, and primary structure in crew compartment shall not exceed plus or minus 4 g acceleration at frequencies above 46 CPS. Vibration levels shall not exceed 0.036 inches double amplitude at frequencies of 46 CPS to 15 CPS. Accelerations greater than plus or minus 4 g's shall not be exceeded at frequencies of 15 CPS to 10 CPS. Vibration shall not exceed 0.080 inches double amplitude at frequencies below 10 CPS.

3.2.14 Aircraft Sustained Operation. The aircraft shall be capable of continued operation subsequent to the flight test program. Design objective service life shall exceed 250 hours.

3.3 Aerodynamics. -

3.3.1 General. - Aircraft design shall maintain smoothness of exterior joints, fairness of surfaces, cleanliness of intersections, and trimness of contours. Protrusions shall be limited to those necessary for antennas, scoops, and holes required for venting.

3.3.2 Stability and Control. -

3.3.2.1 Requirements. - Stability and control characteristics shall be in accordance with Appendix A, entitled XV-5A Flying Qualities. A description of the flight control system is given in paragraph 3.10.

3.3.2.1.1 Stability Augmentation System. - A stability augmentation system (See Figures 25 and 26) shall be provided for use in the fan flight mode to meet requirements specified for attitude stabilization of the aircraft. The system shall consist of pilot controls, system controller, 3-axis gyro package, and amplifier. Two channels; a primary channel (with variable gain features), and a secondary channel acting as stand-by shall be provided.

3.3.2.1.1.1 Aircraft stabilization shall be accomplished by using 3-axis rate gyro signals coupled to hydraulic actuators. Actuator position shall control the wing-fan exit louvers and pitch-fan thrust modulators. In addition to angular rate response, angular position signals shall be provided by electronic integrator networks. In flight, both primary and stand-by channels shall be energized with provisions for pilot selection of either channel.

3.3.2.1.1.2 System operation shall provide two modes; a holding mode, and a maneuvering mode. In the holding mode, $\frac{\beta_s}{s\phi} = K \frac{T_r s + 1}{10s + 1}$ is the overall system transfer function and provides: degrees of louver stagger-angle per fan per degree per second. Gain (K) shall be variable from 0 to 10. The ratio $T_r/10$ shall be adjustable for six preset values of 0.002, 0.01, 0.02, 0.03, 0.05 and 0.10. Gain and ratio adjustment shall be provided in the primary channel only.

3.3.2.1.1.3 In the maneuvering mode, the integrating networks shall be shorted to eliminate position feedback control signals. The overall system transfer function then becomes $\frac{\beta_s}{s\phi} = K'$ providing degrees of louver stagger-angle per fan per degree per second. Gain (K') shall be variable from 0 to 3. Switches in the primary control mixing box shall be used to short the integrating networks, and provide gain control switching. Simultaneous roll and yaw control of the wing-fan exit louvers shall be accomplished by bridge connection of the louver actuators.

3.3.2.1.2 Attitude Control. - All attitude control powers in the lift-fan mode shall be derived entirely from the main engines, making maximum use of inherent functional control capability of the lift-fan system. In event of power loss of either engine, attitude control capability shall not preclude execution of a safe landing.

3.3.2.1.3 Control Requirements, Conventional Flight Mode. - The aircraft shall meet conventional stability requirements of Appendix A without the use of a stability augmentation system.

3.3.2.1.4 Conversion Between Lift-Fan and Conventional Flight Mode. - The pilot shall not be required to remove his hands from the primary controls to accomplish conversion between VTOL and conventional modes of operation. Control transients shall be minimized by proper coordination of longitudinal trim during lift-fan starting or shut-down, and by requiring a minimum power change when shifting between the two modes of operation.

3.3.2.2 Center of Gravity Limits. - See paragraph 3.1.4. and Figure 27. In general, the aircraft center of gravity limits shall be as follows:

(a) Aft limit, Station 246.0
(b) Forward limit, Station 240.0

3.3.2.2.1 The above limits represent the most aft limit from aircraft conventional flight stability considerations, and the most forward limit from hovering trim considerations.

3.3.3 Flutter Characteristics. - The aircraft shall be free from divergence, flutter, buzz, or other aeroelastic instability throughout its range of design speeds, altitudes, maneuvers, and loading and weight conditions. Flutter requirements shall be determined using specification MIL-A-8870 as a guide.

3.4 Structural Design Criteria. - Structural design of the aircraft shall be derived from the requirements of specification MIL-A-8860 and Ryan structural design criteria report No. 62B094. Allowable stress values shall be in accordance with MIL Handbook-5.

3.4.1 Limit Flight Load Factors. - Aircraft design shall be based on flight load factors produced by pull-up/push-over maneuvers, and vertical gusts. See figures 28 and 29. Design strength, for weights greater than basic flight design gross weight, shall be provided by a constant load factor times weight product.

3.4.1.1 Minimum Flying Gross Weight. - 7860 pounds.

Maneuver:	Positive 4.00	Negative 2.00
Gust:	Positive 4.00	Negative 2.00

3.4.1.2 Basic Design Gross Weight. - 9200 pounds.

Maneuver:	Positive 4.00	Negative 2.00
Gust:	Positive 4.00	Negative 2.00

3.4.1.3 Maximum Design Gross Weight. - 12,500 pounds.

Maneuver:	Positive 2.94	Negative 1.47
Gust:	Positive 2.94	Negative 1.47

3.4.2 Landing Load Factors. - The aircraft shall be designed for conventional and vertical landings. Design loads shall provide for conventional landing (basic design gross weight) with the main gear in forward position.

3.4.2.1 Basic Design Gross Weight. - 9200 pounds.

		CTOL	VTOL
Sinking Speed:	Gear forward	10 feet per second	10 feet per second
	Gear aft	6 feet per second	10 feet per second

3.4.2.2 Maximum Landing Gross Weight. - 12,500 pounds.

Sinking Speed: 6 feet per second

3.4.3 Design Speeds. - See Figure 30.

3.4.4 Center of Gravity Limits. - See Figure 27.

3.4.5 Structural Design Service Life. - Structural integrity shall be preserved for a minimum service life of 250 hours distributed at the following flight speeds:

(a) 150 hours at 140 percent stall speed or below.
(b) 75 hours at speed for best cruise.
(c) 25 hours at level flight maximum speed.

3.4.6 Materials. - All construction shall be accomplished using suitable materials for the environmental conditions involved.

3.5 Wing Group. -

3.5.1 Description and Components. - The wing shall be a mid-wing monoplane configuration. Each half span shall consist of an inner panel, housing the lift fan and trailing edge flap, and an outer panel containing the aileron and wing tip. A wing fan inlet closure system consisting of butterfly type doors shall be provided. The doors shall be hinged along the strut fairing of the lift fan in the chord-wise direction. In fan operation, the doors shall open back-to-back through the use of hydraulic actuators. Exit louvers under the fan shall provide an exit closure system.

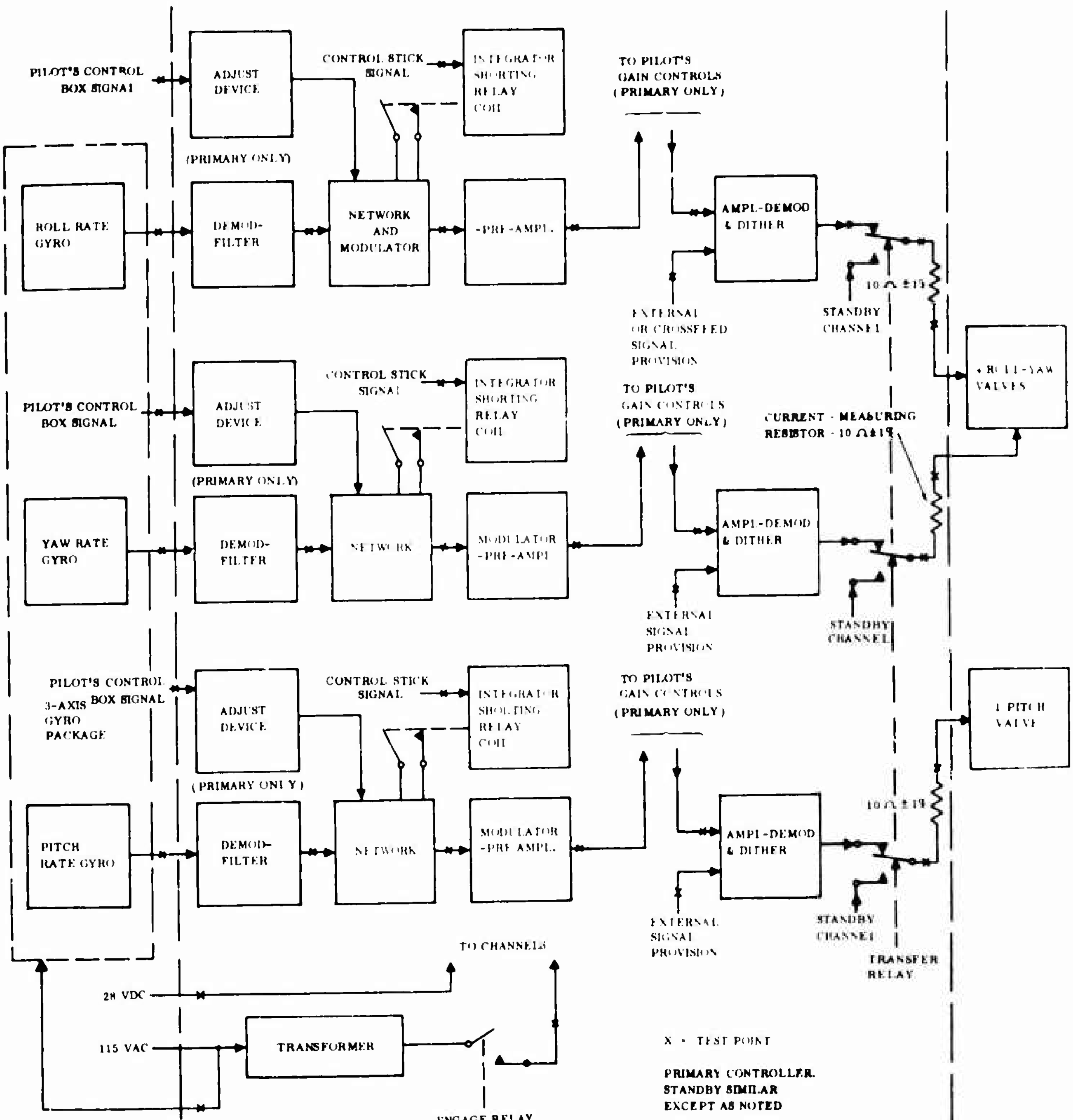


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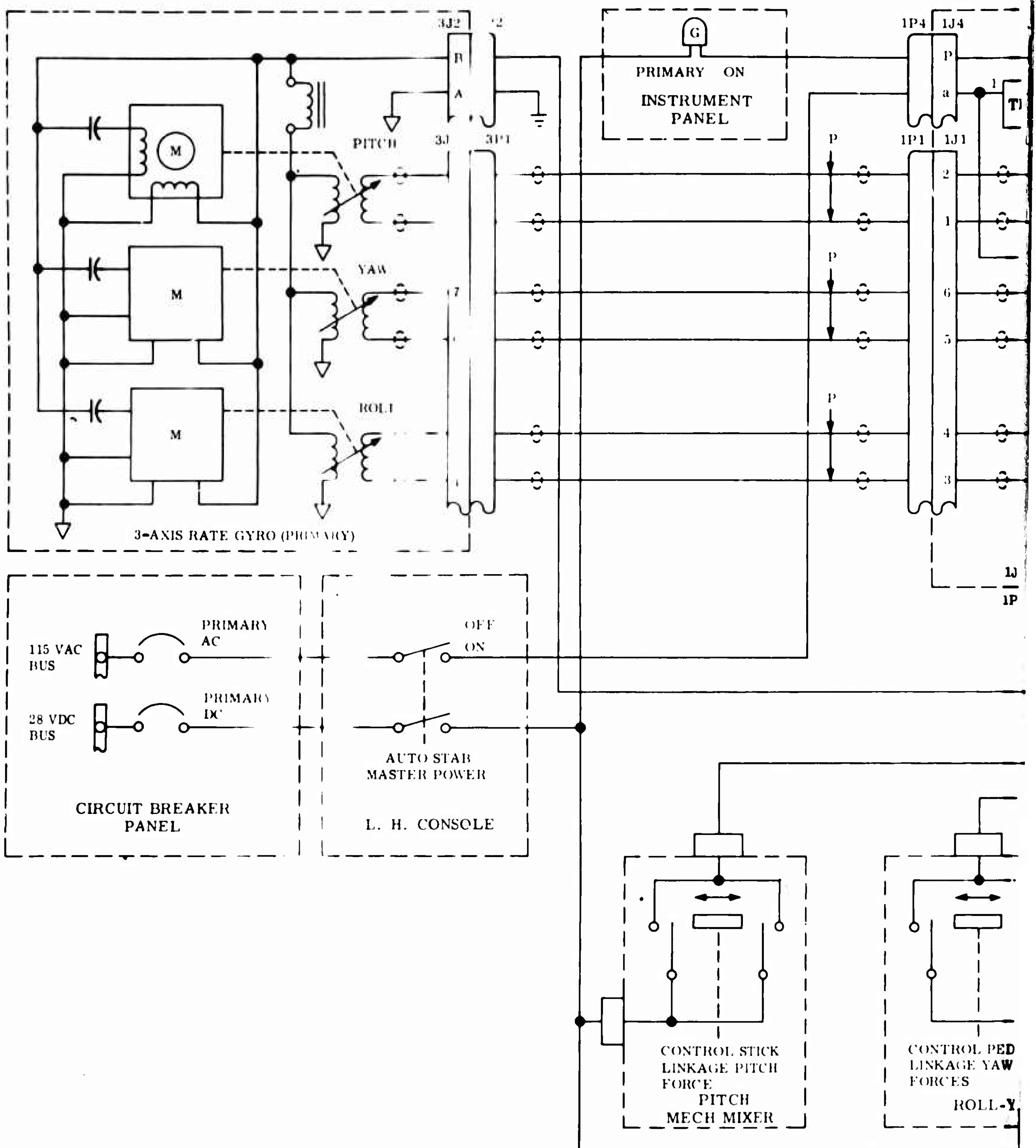
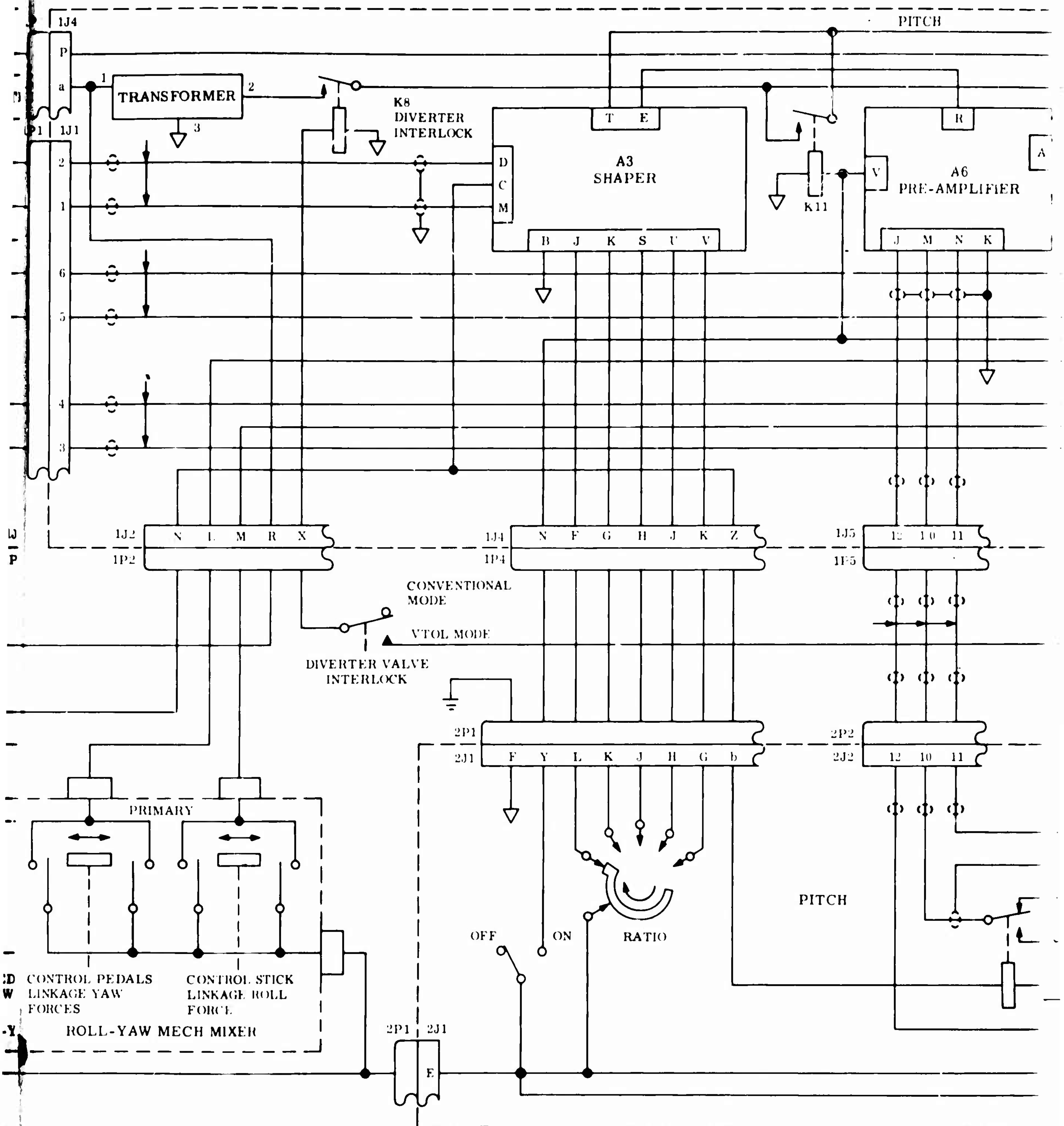
Figure 25 Automatic Stabilization System Block Diagram



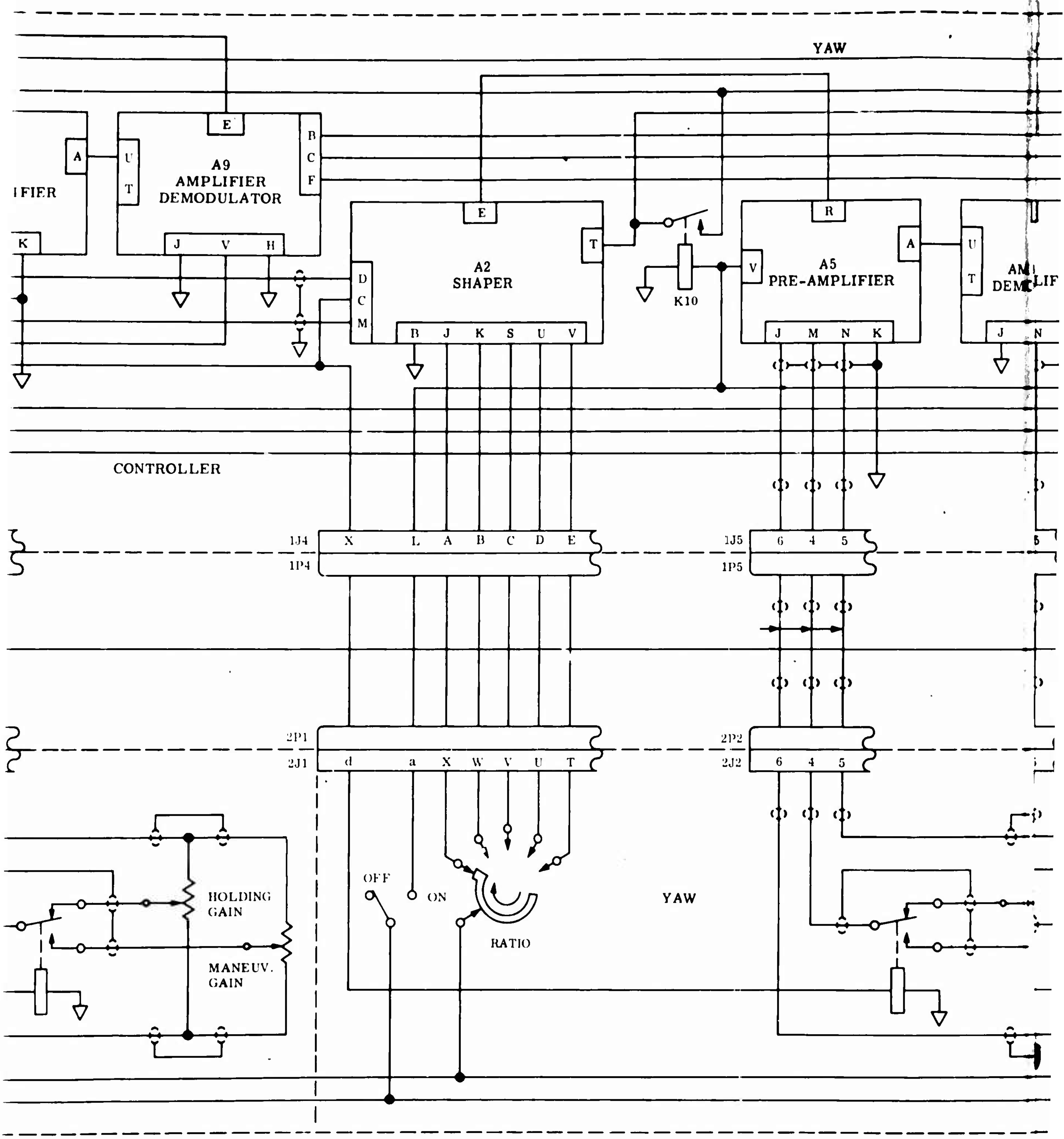
3J2
B
A
M
PITCH
YAW
ROLL
3-AXIS RATE GYRO
G
PRIMARY ON
INSTRUMENT PANEL
1P4
1J4
1P1
1J1
115 VAC BUS
PRIMARY AC
28 VDC BUS
PRIMARY DC
CIRCUIT BREAKER PANEL
OFF
ON
AUTO STAB MASTER POWER
L. H. CONSOLE
CONTROL STICK LINKAGE PITCH FORCE
PITCH MECH MIXER
CONTROL PED LINKAGE YAW FORCES

A



PITCH
1J4
TRANSFORMER
K8
DIVERTER
INTERLOCK
A3
SHAPER
K11
A6
PRE-AMPLIFIER
1J2
1P2
1J4
1P4
1J5
1P5
CONVENTIONAL
MODE
VTOL MODE
DIVERTER VALVE
INTERLOCK
2P1
2J1
2P2
2J2
PRIMARY
PITCH
OFF
ON
RATIO
CONTROL PEDALS
LINKAGE YAW
FORCES
CONTROL STICK
LINKAGE ROLL
FORCE
ROLL-YAW MECH MIXER

B



YAW
A9
AMPLIFIER
DEMODULATOR
IFIER
A2
SHAPER
K10
A5
PRE-AMPLIFIER
CONTROLLER
1J4
1P4
1J5
1P5
2P1
2J1
2P2
2J2
OFF
ON
HOLDING
GAIN
MANEUV.
GAIN
RATIO
YAW

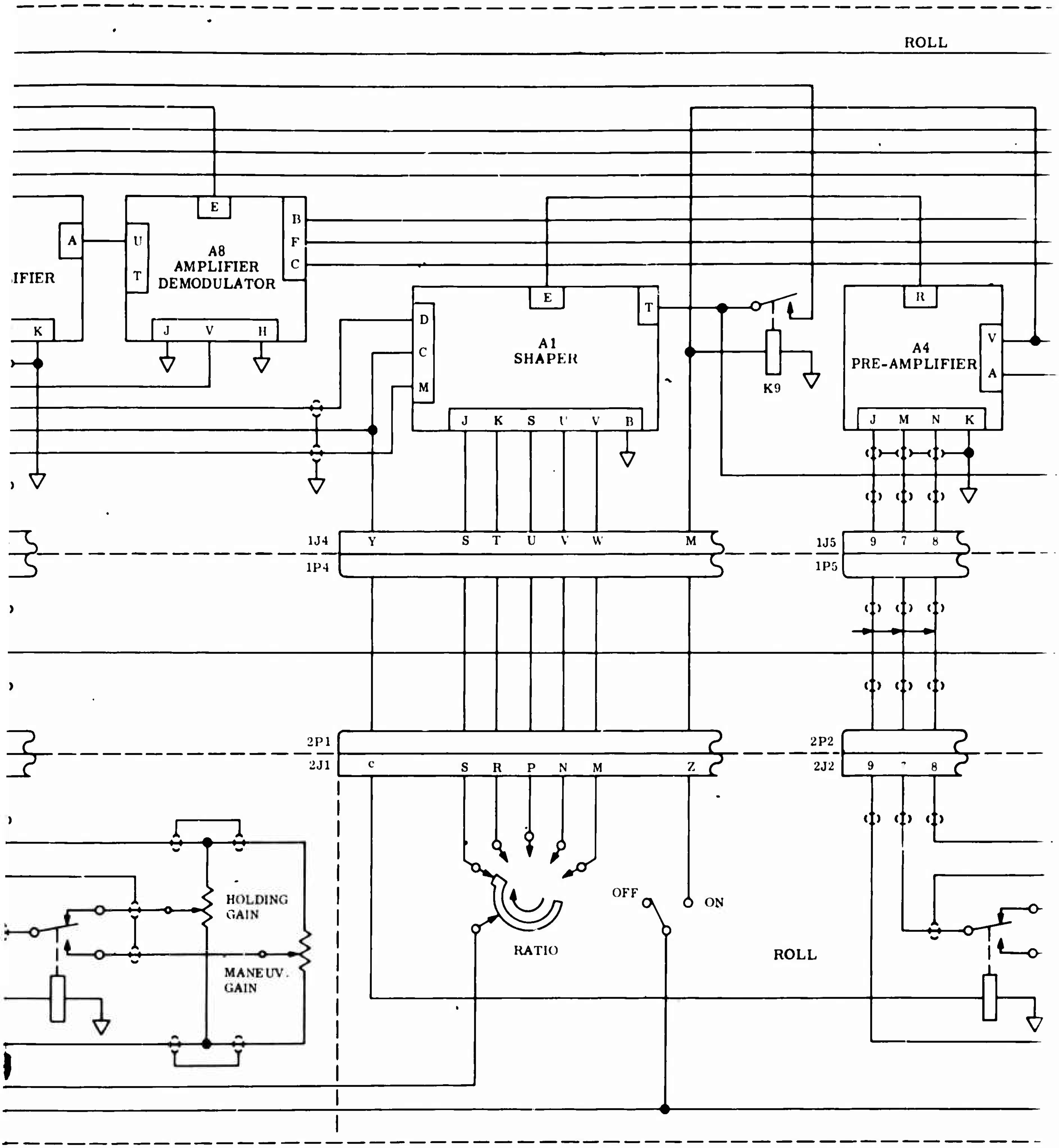


Figure 26 Automatic Sta

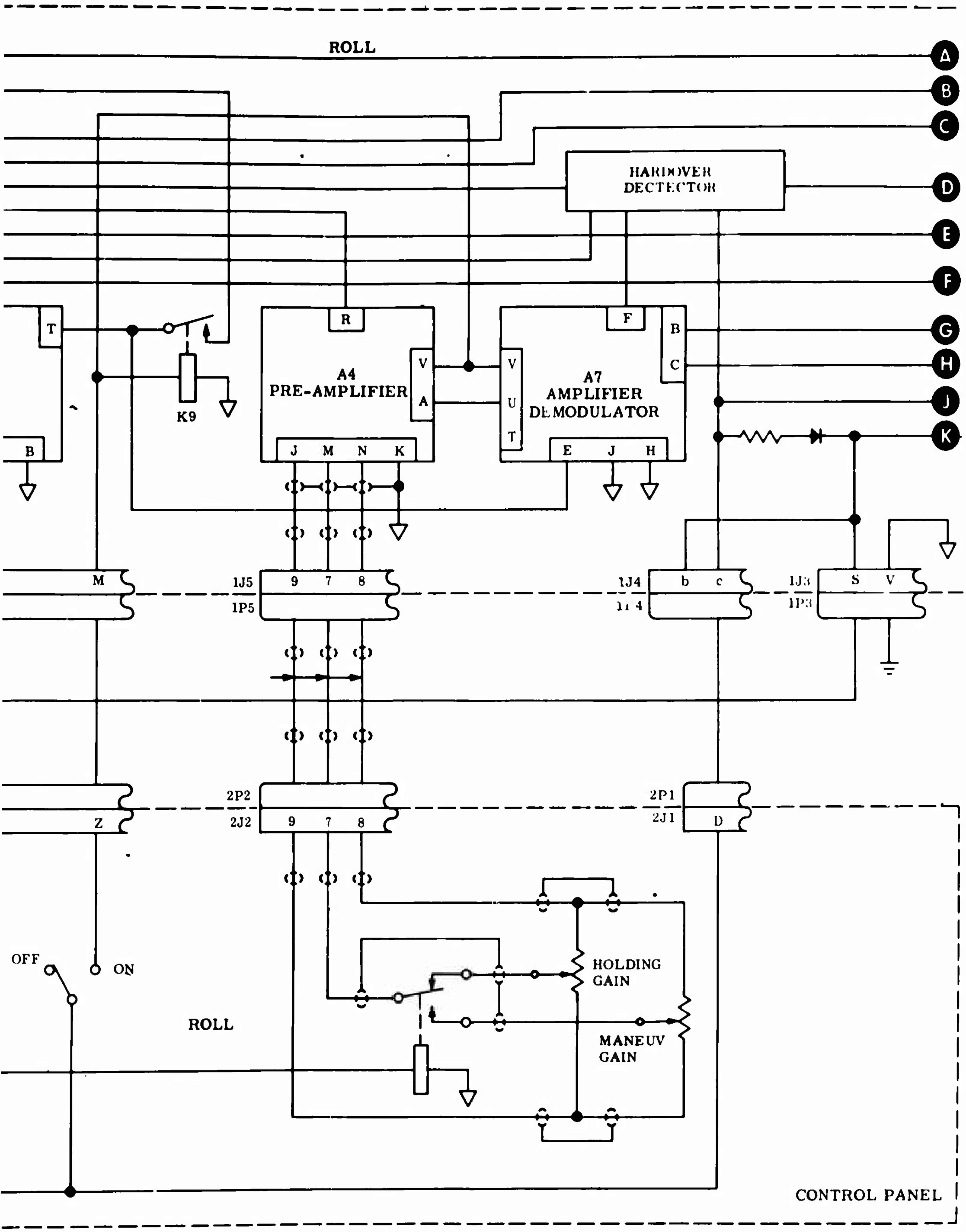
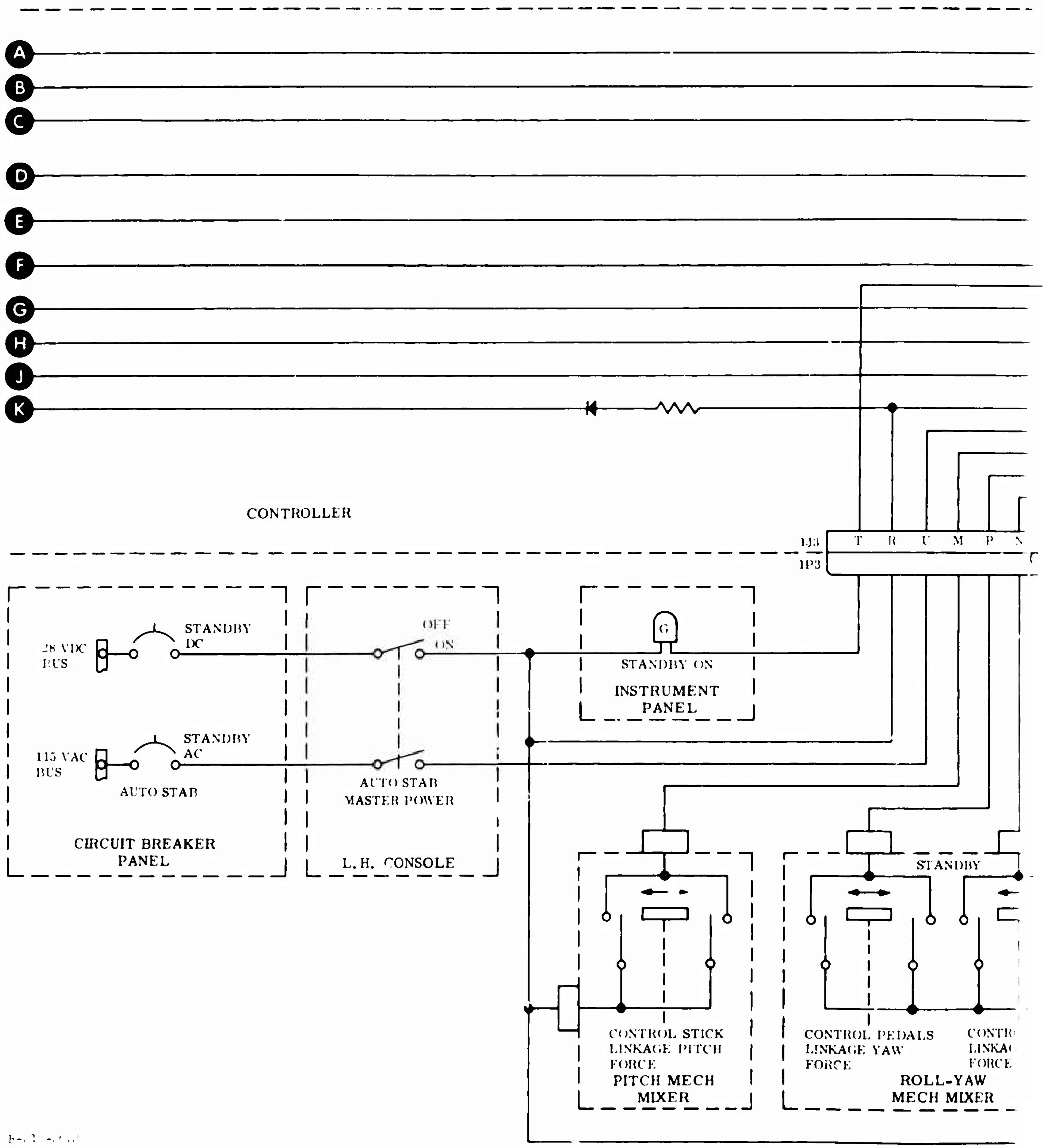
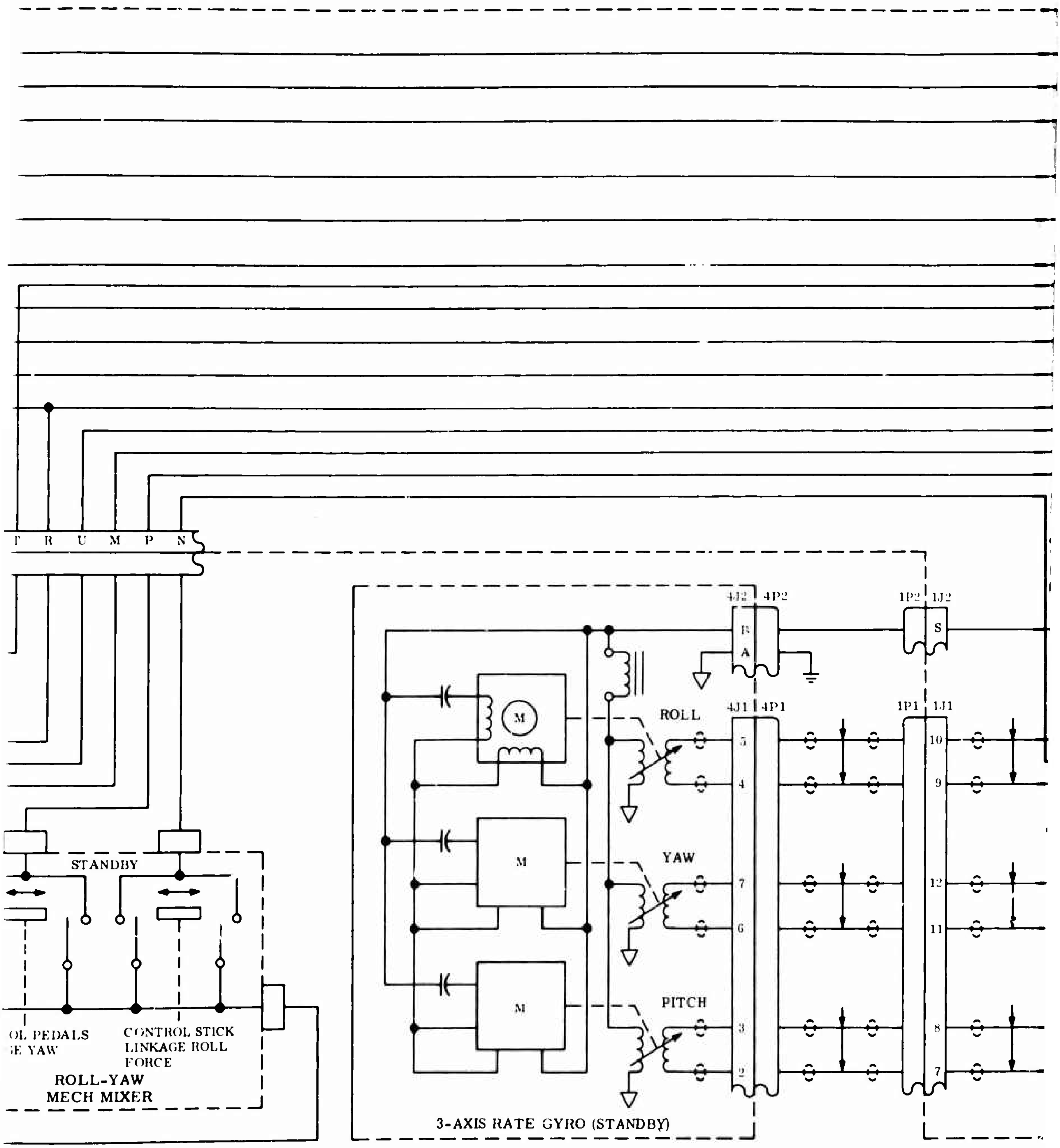


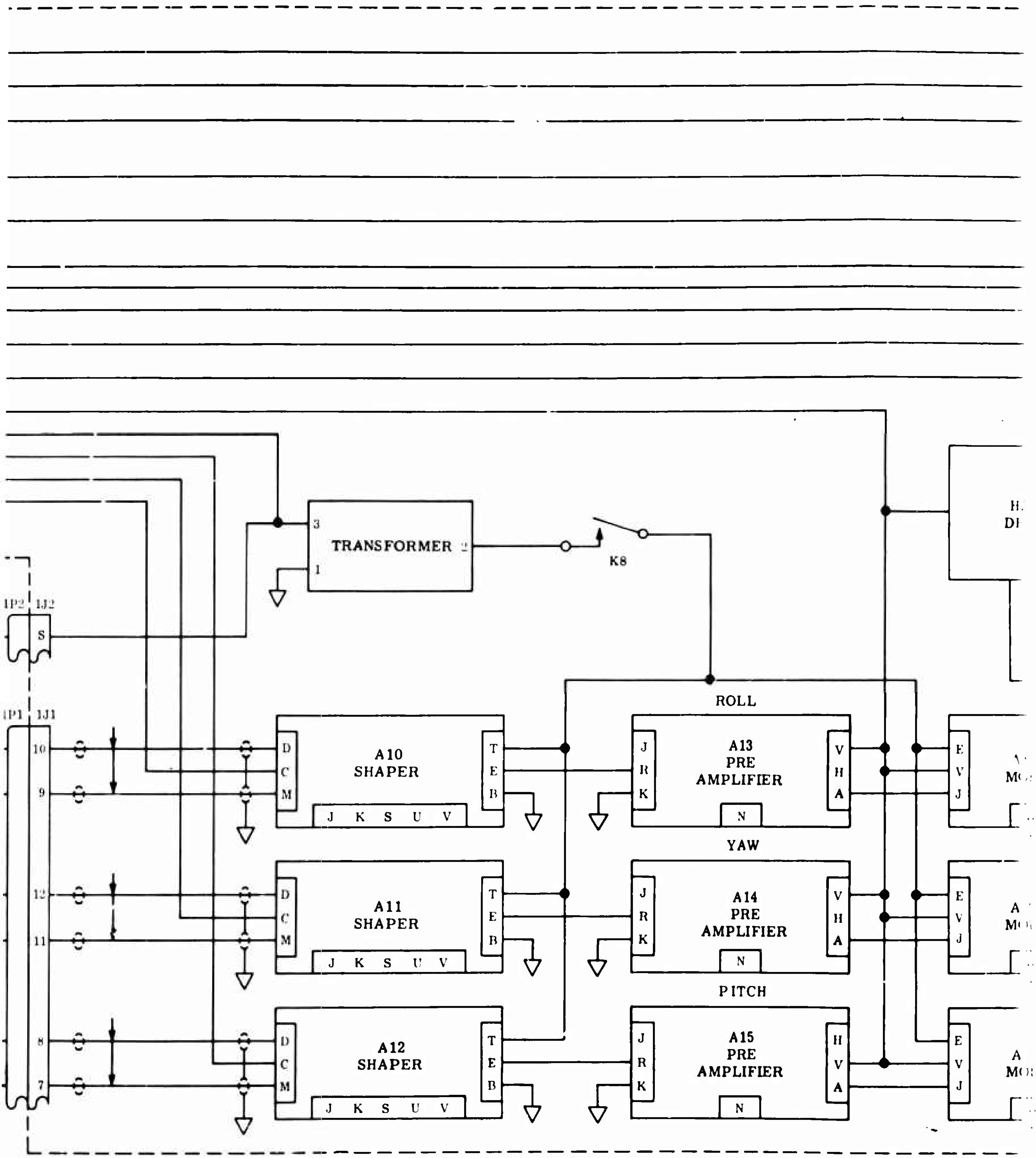
Figure 26 Automatic Stabilization System Schematic Diagram (Sheet 1 of 2)


A
B
C
D
E
F
G
H
J
K
CONTROLLER
1J3
1P3
T R U M P N
28 VDC BUS
STANDBY DC
115 VAC BUS
STANDBY AC
AUTO STAB
CIRCUIT BREAKER PANEL
OFF
ON
AUTO STAB MASTER POWER
L.H. CONSOLE
G
STANDBY ON
INSTRUMENT PANEL
CONTROL STICK LINKAGE PITCH FORCE
PITCH MECH MIXER
STANDBY
CONTROL PEDALS LINKAGE YAW FORCE
ROLL-YAW MECH MIXER

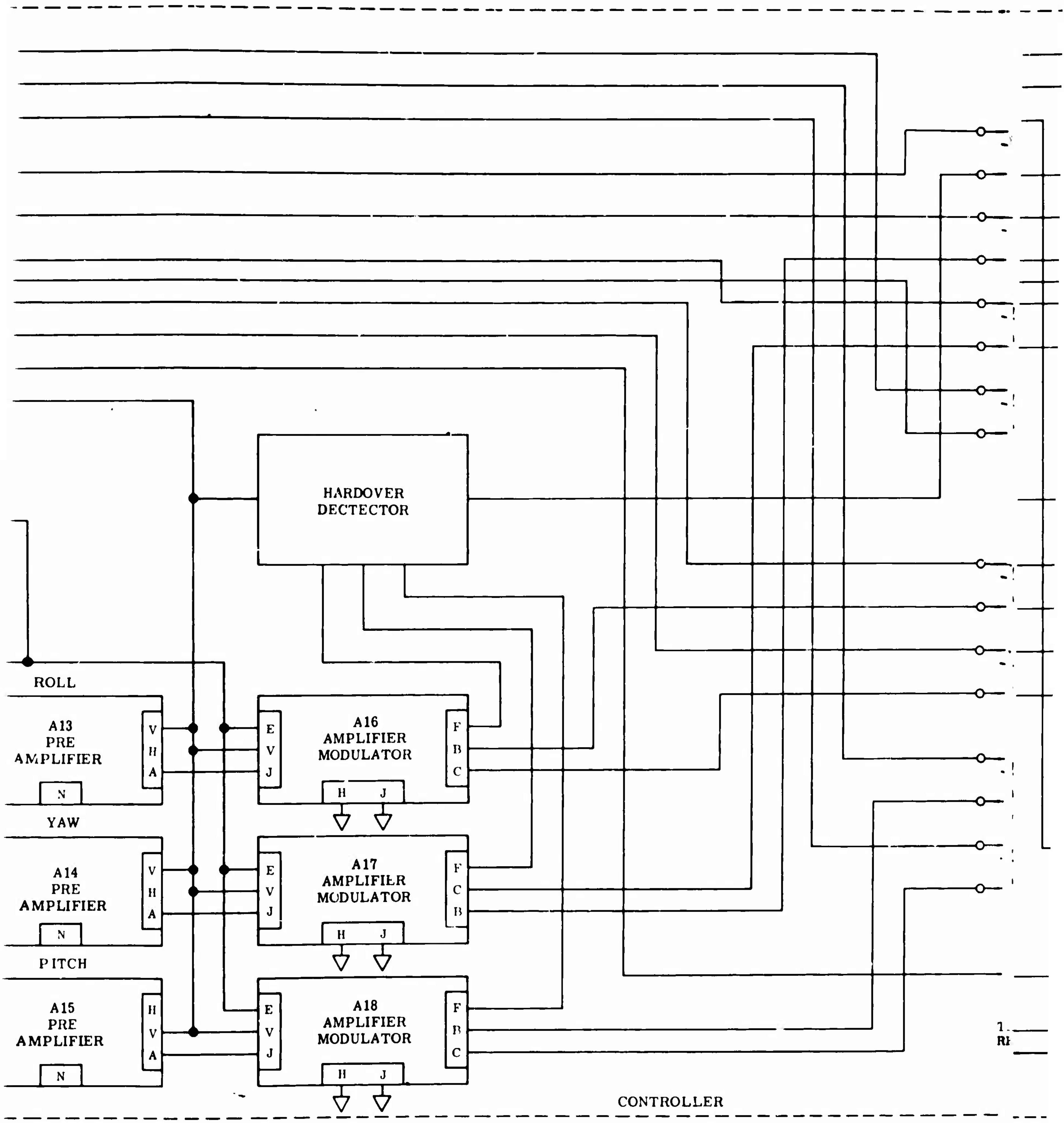
A



T R U M P N
STANDBY
OL PEDALS
E YAW
CONTROL STICK
LINKAGE ROLL
FORCE
ROLL-YAW
MECH MIXER
4J2 4P2
1P2 1J2
4J1 4P1
1P1 1J1
ROLL
YAW
PITCH
3-AXIS RATE GYRO (STANDBY)


TRANSFORMER
K8
1P2
1J2
1P1
1J1
ROLL
A10
SHAPER
A13
PRE
AMPLIFIER
YAW
A11
SHAPER
A14
PRE
AMPLIFIER
PITCH
A12
SHAPER
A15
PRE
AMPLIFIER

C


HARDOVER DECTECTOR
ROLL
A13 PRE AMPLIFIER
YAW
A14 PRE AMPLIFIER
PITCH
A15 PRE AMPLIFIER
A16 AMPLIFIER MODULATOR
A17 AMPLIFIER MODULATOR
A18 AMPLIFIER MODULATOR
CONTROLLER

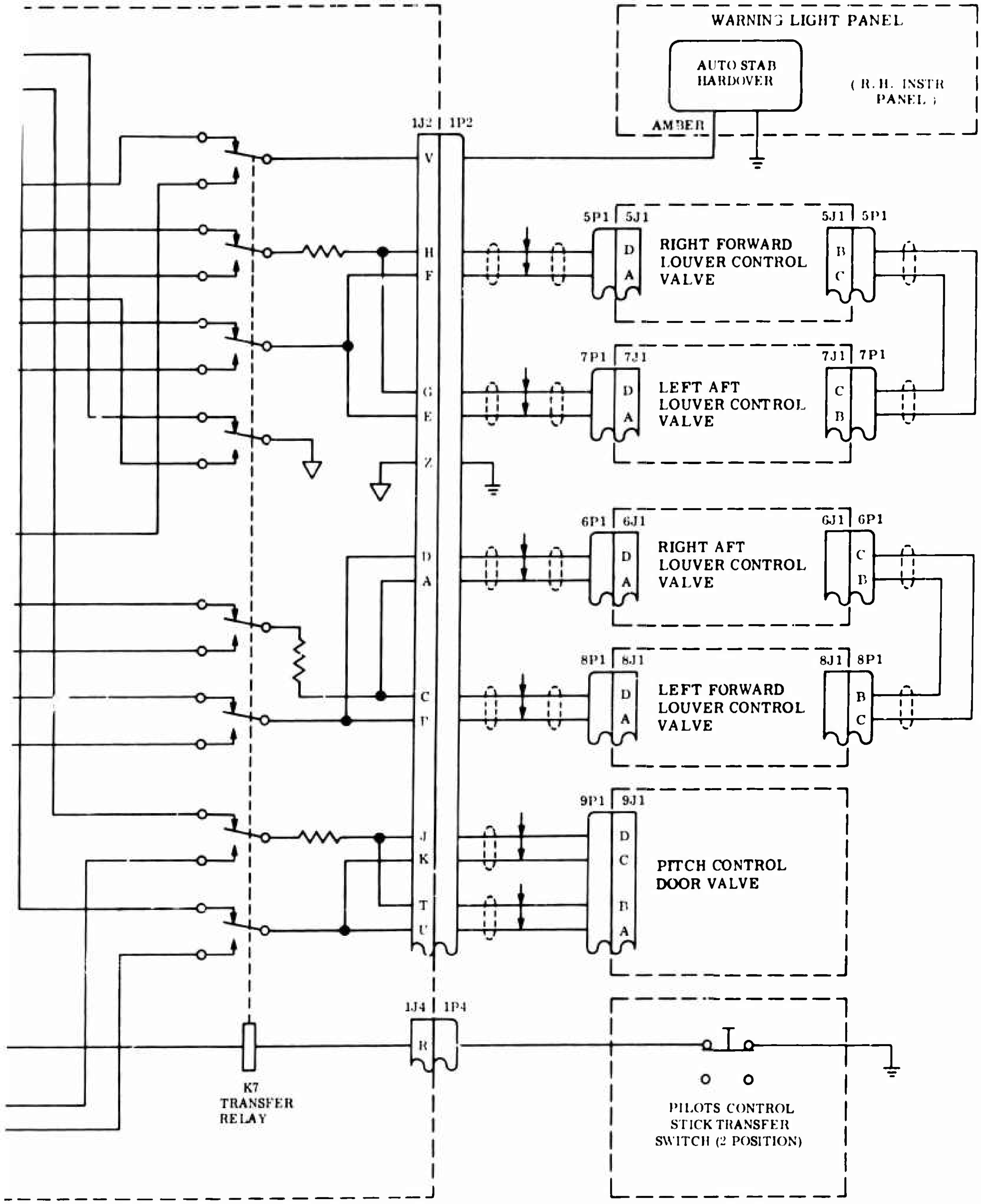


Figure 26 Automatic Stabilization System Schematic Diagram (Sheet 2 of 2)

CENTER OF GRAVITY LIMITS

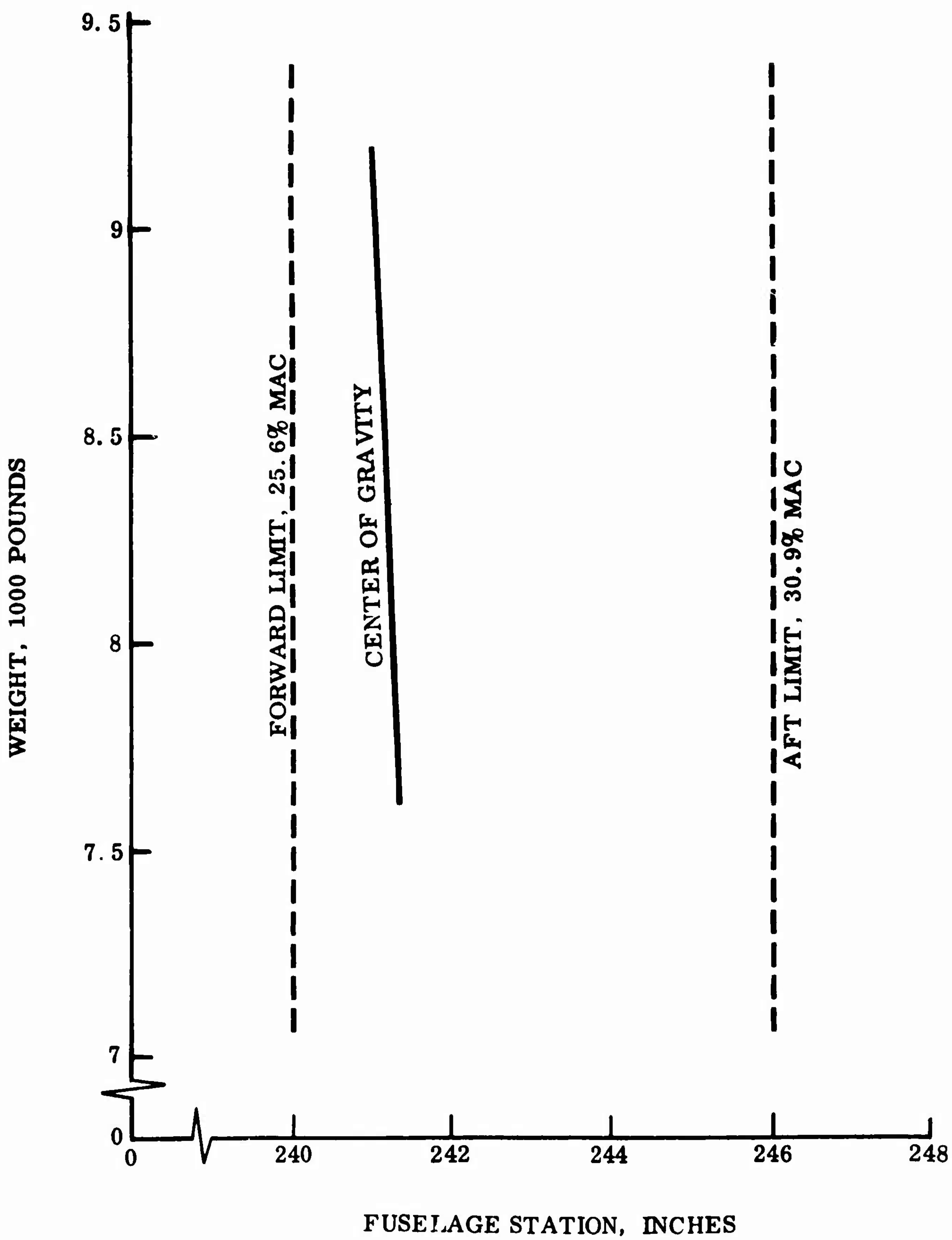


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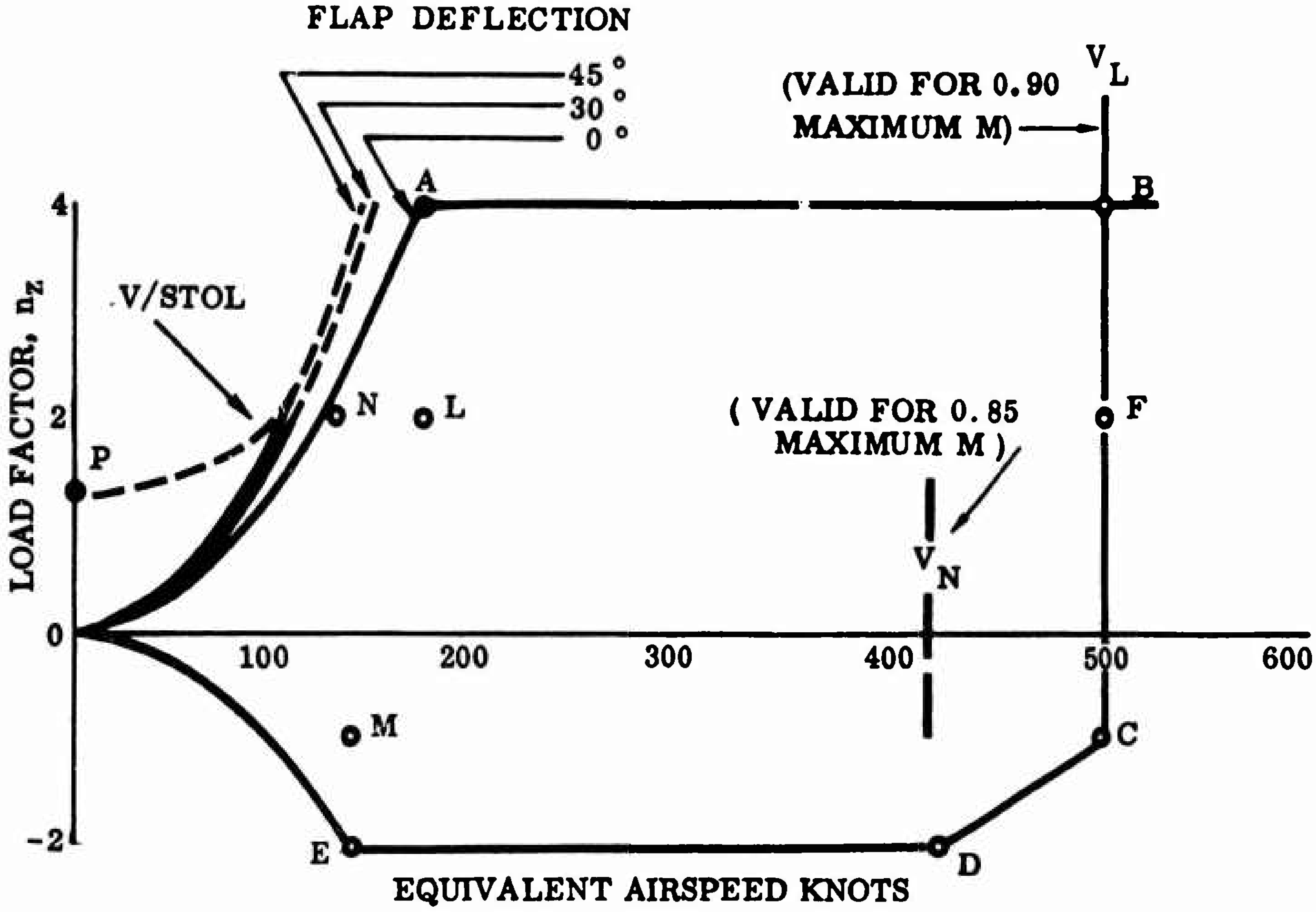
Figure 27 Center of Gravity Limits



Associated Angular Motion

Point	$\dot{\omega}y$, rad/sec^2	ωy, rad/sec
A	3.000	-1.50 $\sigma^{1/2}$
B	1.500	-0.152 $\sigma^{1/2}$
C	-1.500	0.019 $\sigma^{1/2}$
D	-3.000	0.091 $\sigma^{1/2}$
E	-3.000	0.029 $\sigma^{1/2}$
F	-1.500	-0.228 $\sigma^{1/2}$
L	-3.000	-0.680 $\sigma^{1/2}$
M	3.000	0.043 $\sigma^{1/2}$
N	-3.000	-0.610 $\sigma^{1/2}$
P	$\pm$0.698	$\pm$7.000

NOTE: Positive Values of $\dot{\omega}y$ and ωy indicate aircraft pitch-over

Figure 28 Maneuvering Envelope

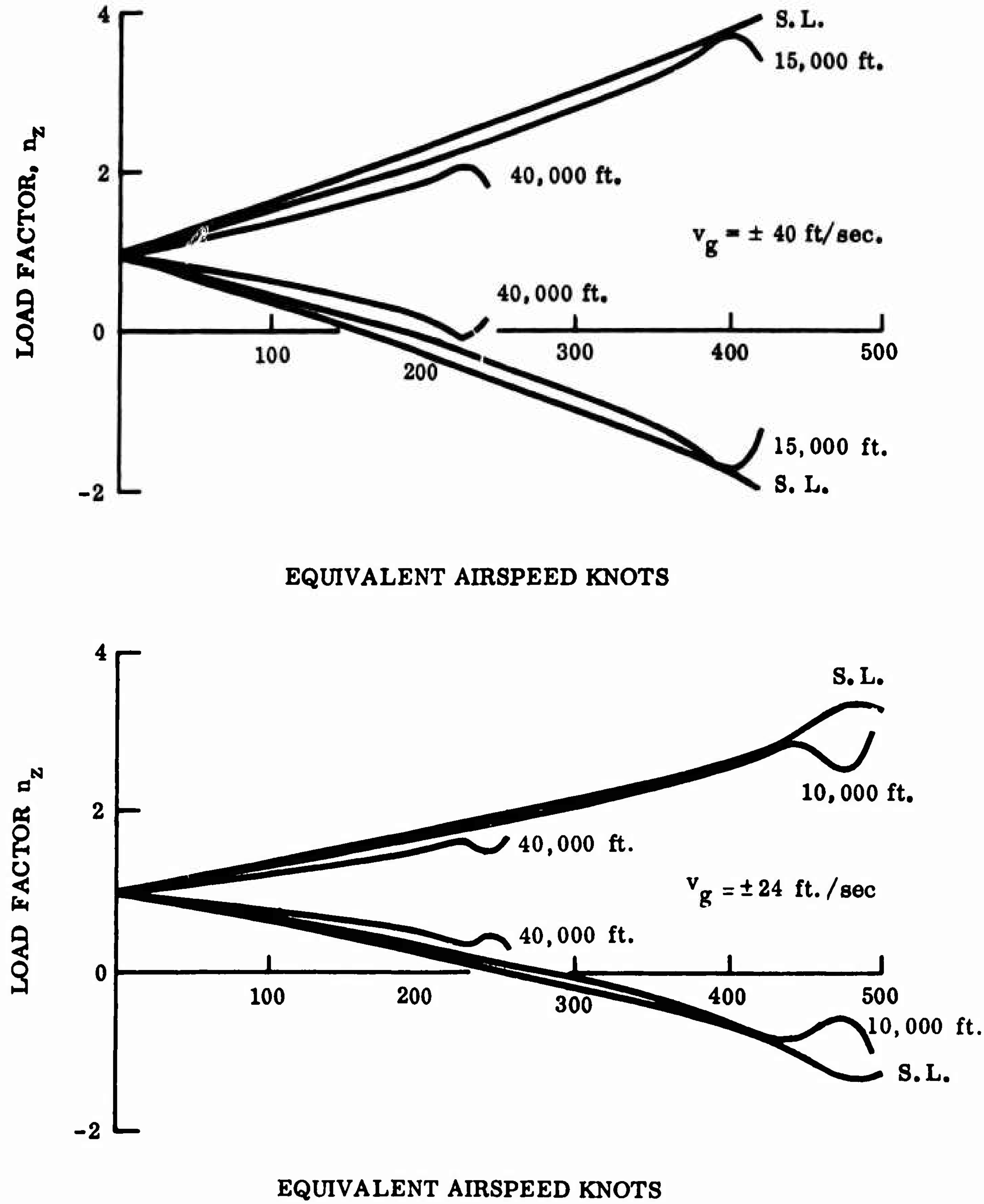


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Figure 29 Gust Diagram

DESIGN SPEEDS
ARDC STANDARD DAY

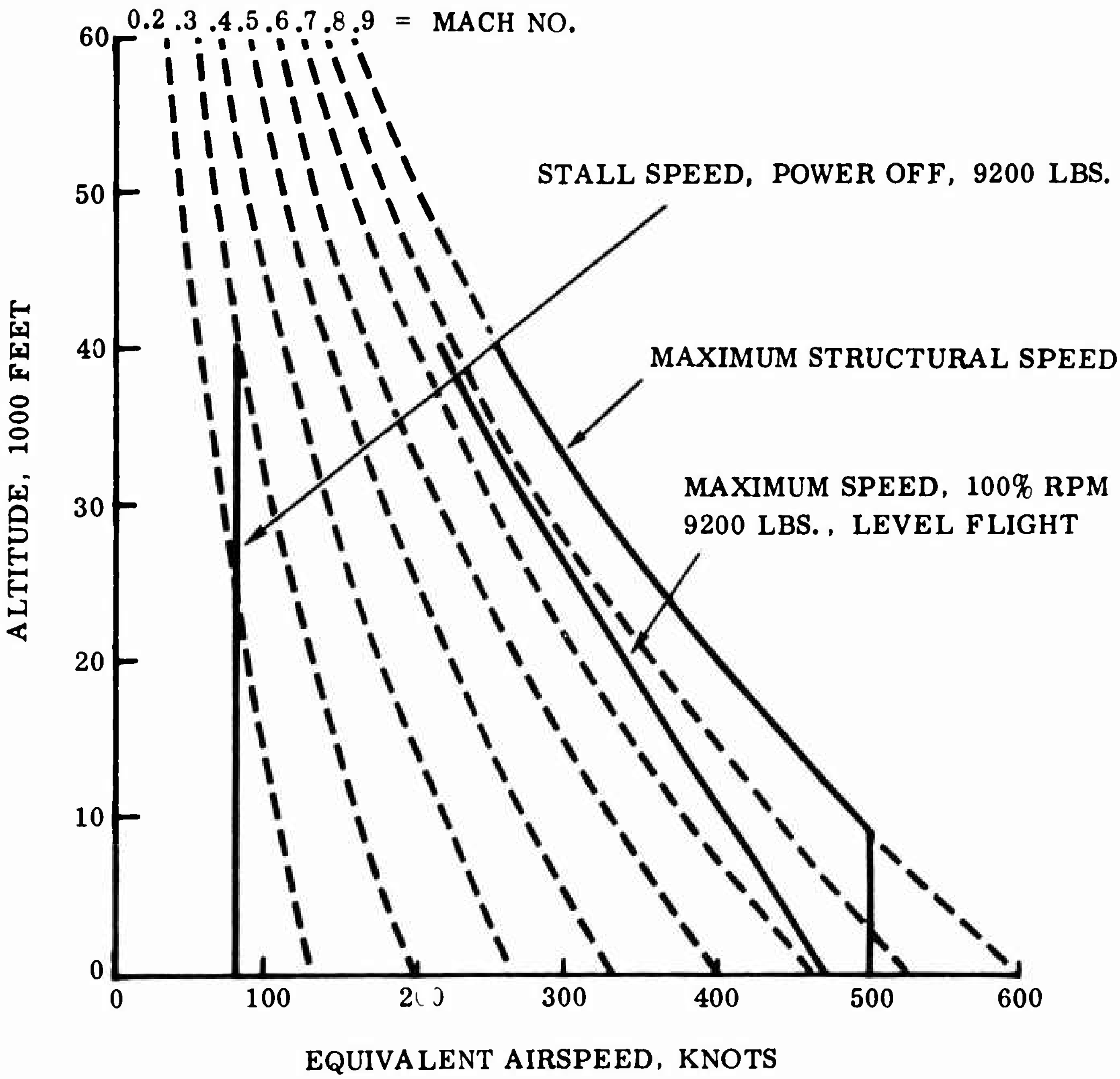

Figure 30 Design Speeds

3.5.2 Construction. - Wing structure (see Figure 31) shall utilize two half span spars connected to the fuselage inter-spar structure. Multiple rib-type construction shall be used for skin stiffening and load carrying. A main rib, outboard of the lift fan, shall be utilized to distribute loads from the outboard wing panel to the inboard wing panel. Wing loads shall be carried from the stiffened skin, to the ribs, and beamed into the forward and aft spars. The wing spars are connected to the inter-spar structure in the fuselage and transmit wing reaction loads into bulkheads located at each spar. Wing torsion is transmitted to the fuselage and distributed into the bulkheads through differential spar bending. Shear loads are handled by fuselage skin panels. Wing fan loads are distributed at three locations. The primary fan mount is located at the forward spar on the chord center line of the fan and accepts reaction loads in all directions from the fan. The aft fan mount is attached to the aft wing spar and accepts vertical and lateral reactions. A third mount is located at the span-wise center line in the fuselage and reacts to vertical, forward, and aft loads.

3.5.2.1 Wing materials shall be aluminum and fiberglas. Inboard wing skins, and all wing spars, shall be made of aluminum alloy. Outboard wing panel skins shall be made of aluminum alloy. The wing tip shall be made of fiberglas.

3.5.3 Ailerons. - Ailerons shall be single spar, ribbed construction (see Figure 31) made of aluminum alloy. All skins shall be magnesium. An aerodynamic balance seal shall be attached to the leading edge of the aileron. Aileron trim shall be provided.

3.5.4 Lift Devices. - Single-slotted flaps shall be installed on the inboard trailing edge of each wing. Flaps shall be single spar construction (see Figure 31) made from aluminum alloy. An aileron droop system shall be included to operate in conjunction with the wing flaps to provide additional lift.

3.6 Tail Group. -

3.6.1 Description and Components. - The tail group shall be a "tee" configuration consisting of horizontal stabilizer, elevator, vertical fin, rudder, and rudder trim tab.

3.6.2 Stabilizer. - The horizontal stabilizer shall be an all-movable configuration and shall be located at the top of the vertical fin. Construction shall consist of ribs and skin attached to spars (see Figure 31). The primary spar is attached to the vertical fin at two mounting points. The stabilizer actuator attaches to the forward spar, providing three mounting points. Stabilizer spars and ribs shall be made of aluminum alloy covered with magnesium alloy skins.

3.6.3 Elevators. - Elevators shall be single spar construction with conventional ribs (see Figure 31). The elevator shall be hinged at the horizontal stabilizer aft spar and actuated by conventional control cable and bellcrank system.

3.6.4 Fin. - The vertical fin shall consist of three-spar construction (see Figure 31) with conventional ribs and skin. The rear spar shall provide support for the rudder. The three spars shall form a torque box and serve to support the stabilizer attachment fittings. Spars and ribs shall be aluminum alloy. Skins shall be magnesium.

3.6.5 Rudder. - The rudder shall be single spar construction (see Figure 31) with conventional ribs. Spar and ribs shall be made of aluminum alloy. Magnesium alloy skins shall be used. The rudder shall contain a directional trim tab located on the trailing edge.

3.7 Body Group. -

3.7.1 Fuselage. -

3.7.1.1 Description. - The fuselage shall provide for a nose fan and thrust modulating mechanism, located in the forward portion of the fuselage. The pilot's compartment shall be located aft of the nose fan and accommodate 1 pilot and 1 passenger or observer. The nose alighting gear shall be located beneath the pilot's compartment and retract forward. An integral fuel tank shall be installed in the area behind the cockpit. The gas producers and diverter valves shall be located above the wing in the top portion of the fuselage. The center bay of the fuselage shall accommodate the avionics equipment, cross-over ducts, forward main fuel tank and nose fan bleed ducts. The aft bay of the fuselage shall accommodate the aft main fuel tank, engine exhaust pipes, and main landing gear. Heat shielding and firewalls shall be provided to protect equipment and personnel from bleed duct and power plant heat dissipation.

3.7.1.2 Construction. - The fuselage shall be semi-monocoque construction (see Figure 31) with exception of the center bay which shall be space frame construction incorporating non-structural access panels. Space frame structure shall act as the primary load carrying system between the forward and aft spar bulkheads. The space frame shall also serve as a power plant and cross-over duct mounting. The aft fuselage shall consist of a five-longeron system on each side of the fuselage. Three aft fuselage frames shall be integral with the vertical fin spars. A bulkhead shall be provided to distribute landing loads in the fuselage. The fuselage shall be constructed of aluminum alloy. Skin areas carrying light structural loads shall be made of magnesium alloy. The forward fuselage fairing shall be reinforced fiberglas.

3.7.1.3 Crew Station Subsystems. - The crew station (Figure 32) shall be located in the forward fuselage section behind the nose fan. Side-by-side seating shall be provided for pilot and passenger. A North American LW-2 ejection escape system shall be provided for the crew. The pilot shall be located on the left side of the cockpit and have complete operational authority. The right-hand station shall be provisioned for an observer or flight data acquisition system. Instrumentation shall be provided for VFR conditions. Crew station access shall be gained through a manually operated canopy, hinged at the aft end. The canopy shall be designed for removal under emergency egress conditions and for through-the-canopy ejection at low altitudes.

3.7.1.3.1 Oxygen System. - A gaseous oxygen breathing system shall be installed as part of the seat system, and shall be for emergency use only.

3.7.1.4 Cargo Compartments. - Not applicable.

3.7.1.5 Equipment Compartments. - A readily accessible equipment compartment shall be provided in the fuselage aft of the cockpit bulkhead. Additional compartment space shall be provided in the lower fuselage bay, and between the nose fan bleed ducts. Compartment space the lower fuselage bay (presently housing extended range fuel tanks), may be used for additional stores.

3.8 Alighting Gear. -

3.8.1 General Description and Components. - Alighting gear shall consist of main landing gear and nose landing gear. Both gears shall be completely retractable into the fuselage. Mechanical down and up locks with cockpit indication shall be provided.

3.8.2 Main Landing Gear. -

3.8.2.1 Description. - Each main landing gear shall consist of a vertical acting shock strut, supporting structure and wheel and brake assembly (see Figure 33). The gear shall pivot about a trunnion rigidly attached to the fuselage bulkhead. The landing gear assembly shall have provisions for two positions. The forward position shall be for conventional flight and STOL; the aft position shall be for VTOL flight operations. Retraction and extension shall be accomplished hydraulically. An emergency, pneumatic, gear extension system shall be provided to permit gear extension in event of hydraulic system pressure loss.

3.8.2.2 Wheels, Brakes, and Brake Control Systems. - The main landing gear wheel shall be 20 by 4.4 in accordance with specification MIL-W-5013E. Each wheel shall be capable of rolling under design gross weight conditions a minimum of 1000 miles. The braking system shall be capable of at least 10 stops at 6.4 feet per second per second average deceleration. Toe-operated pedals shall be provided for brake operation. Braking locks shall not be provided.

1. Nose Cone
2. Forward Bulkhead, Pitch-fan
3. Forward Fuselage Section
4. Aft Bulkhead, Pitch-fan
5. Windshield (Ref)
6. Canopy (Ref)
7. Front Spar Bulkhead
8. Canted Bulkhead, Forward Fuselage
9. Lower Longeron, Forward Fuselage, L. H.
10. Upper Longeron, Forward Fuselage, L. H.
11. Wing, R. H.
12. Aileron, R. H.
13. Flap, R. H.
14. Right Hand Engine Master Mounts
15. Left Hand Engine Master Mounts
16. Center Fuselage Space Frame
17. Rear Spar Bulkhead
18. Aft Fuselage Section
19. External Longeron
20. Upper Longeron, Aft Fuselage, L. H.
21. Vertical Stabilizer Leading Edge Fairing
22. Vertical Stabilizer
23. Vertical Stabilizer Rear Spar
24. Vertical Stabilizer Center Spar
25. Tail Cone
26. Vertical Stabilizer Rear Spar Bulkhead
27. Vertical Stabilizer Forward Spar
28. Vertical Stabilizer Rib
29. Vertical Stabilizer Center Spar Bulkhead
30. Vertical Stabilizer Forward Spar Bulkhead
31. Tailpipe Aft Bulkhead
32. Tailpipe Exhaust Fairing
33. Lower Longeron, Aft Fuselage, L. H.
34. Rear Wing Spar Fuselage Attach Structure
35. Rudder
36. Rudder Trim Tab
37. Horizontal Stabilizer
38. Horizontal Stabilizer Forward Spar
39. Horizontal Stabilizer Tip
40. Horizontal Stabilizer Center Spar
41. Horizontal Stabilizer Rear Spar
42. Horizontal Stabilizer Rib
43. Elevators
44. Elevator Rib
45. Flap, L. H.
46. Aileron, L. H.
47. Aileron Aft Spar, L. H.
48. Aileron Rib, L.H.
49. Aileron Front Spar, L. H.
50. Wing Aft Spar, L. H.
51. Cap Rib
52. Wing Tip, L. H.
53. Outboard Wing Panel, L. H.
54. Leading Edge Fairing
55. Wing Front Spar, L. H.
56. Inboard Wing Panel
57. Nose Fan Pitch Control Doors (Ref.)
58. Main Landing Gear (Ref.)
59. Main Landing Gear Doors (Ref.)
60. Nose Landing Gear (Ref.)
61. Aileron Trim Tab
62. Center Fuselage Access Cover (Ref.)
63. Center Fuselage Removable Canoe (Ref.)

ge, L. H.
ach Structure
d Spar
Spar
par
rs (Ref.)
ef.)
er (Ref.)
Canoe (Ref.)

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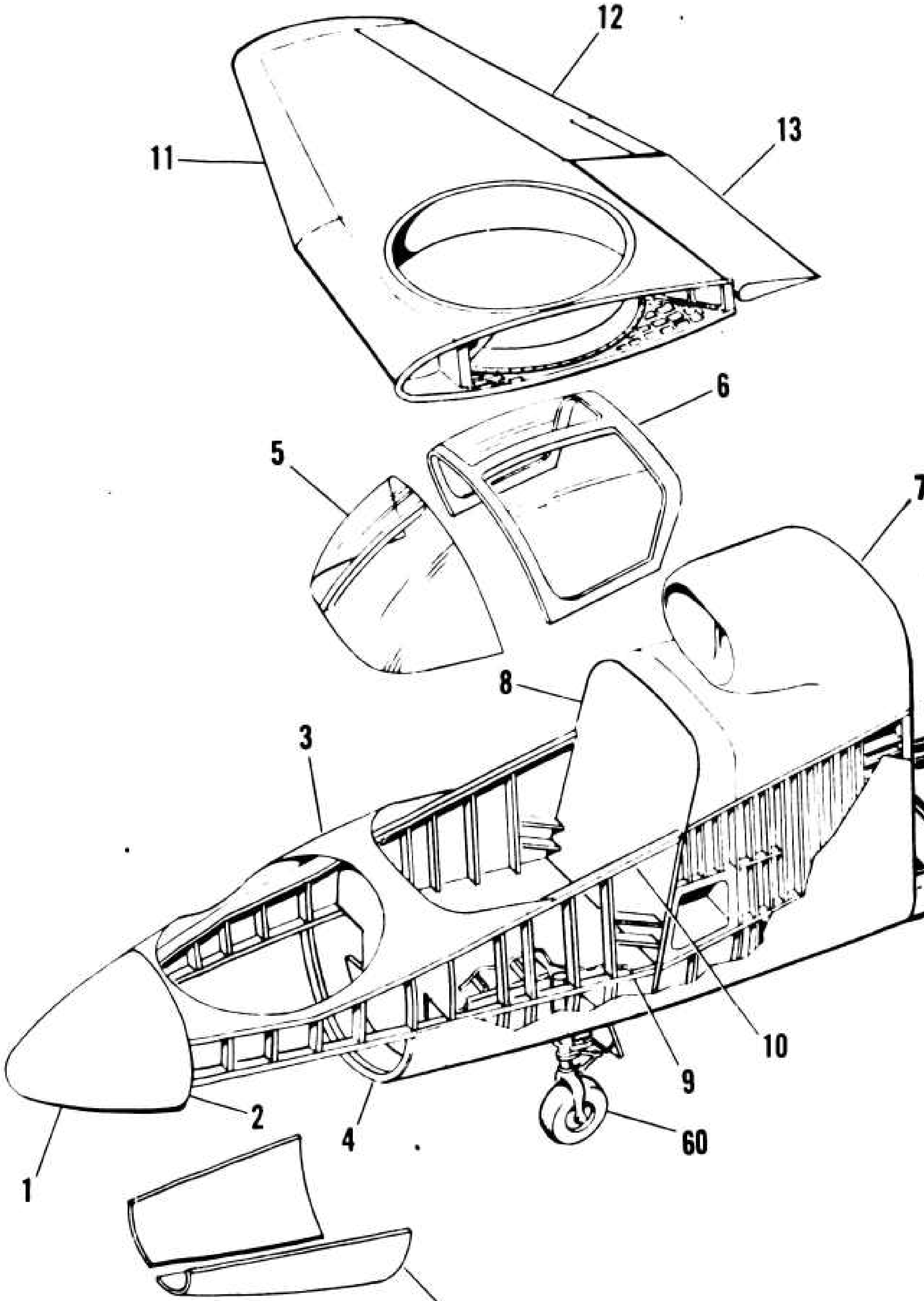

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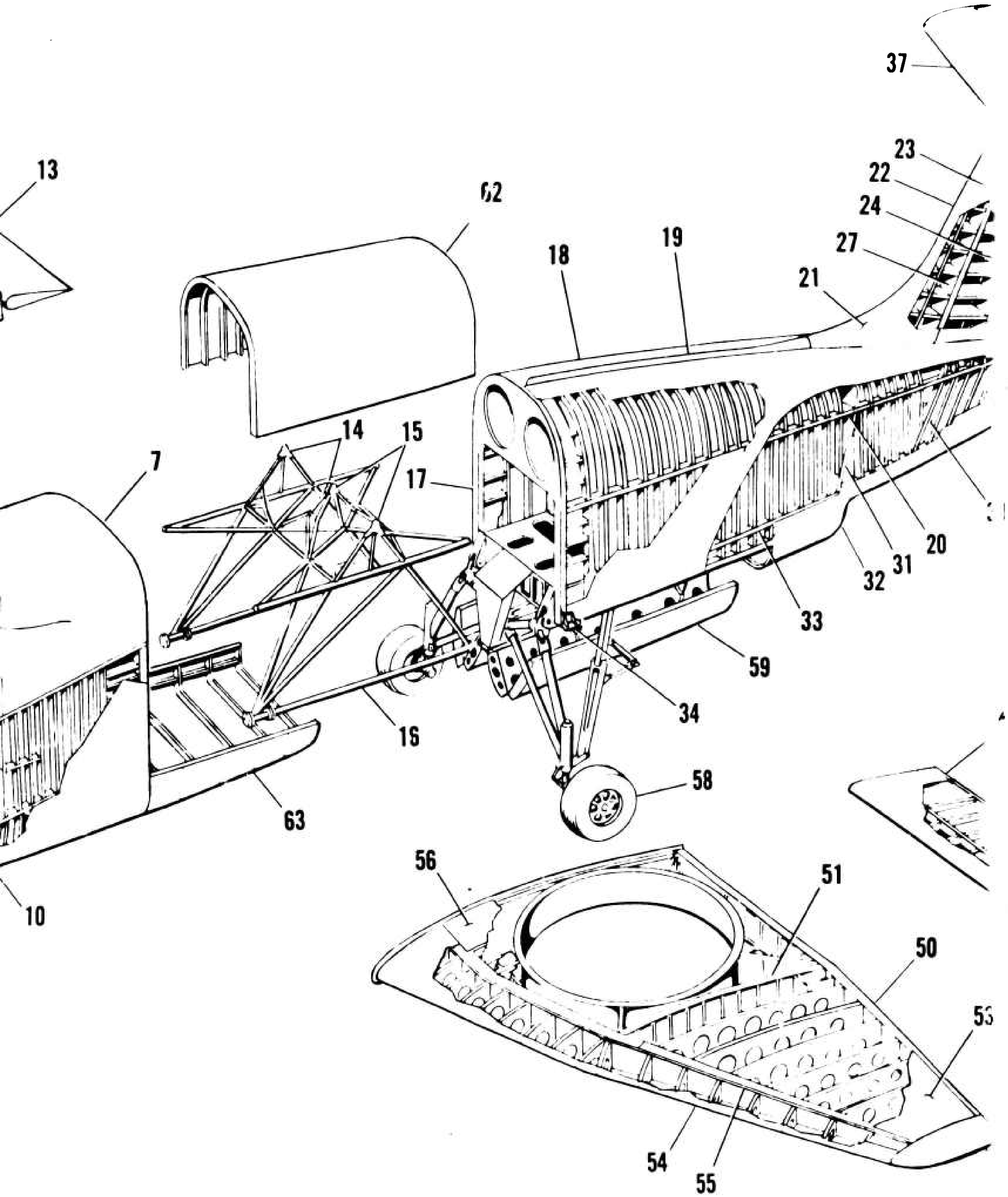


Figure 31 Aircraft

C

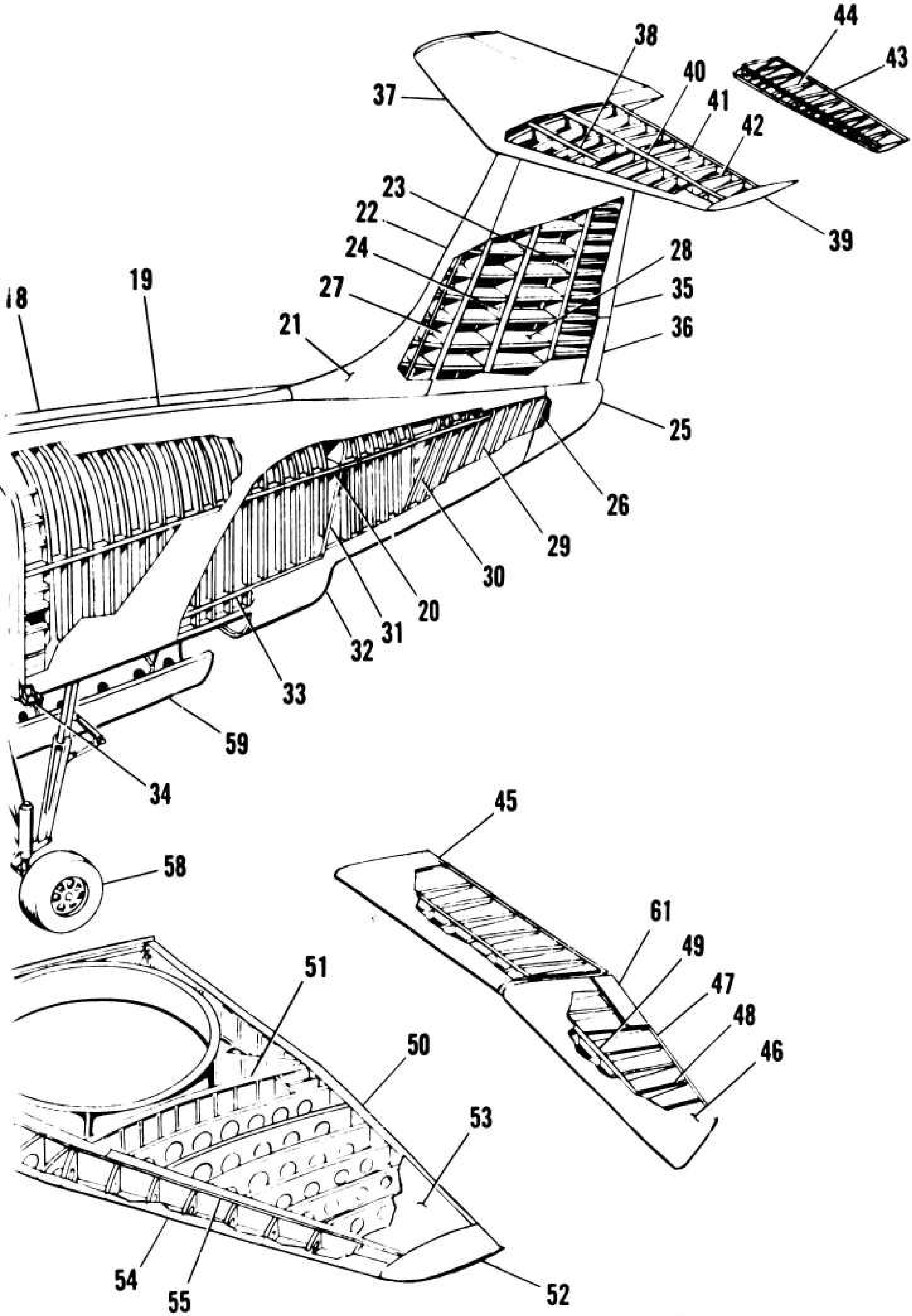
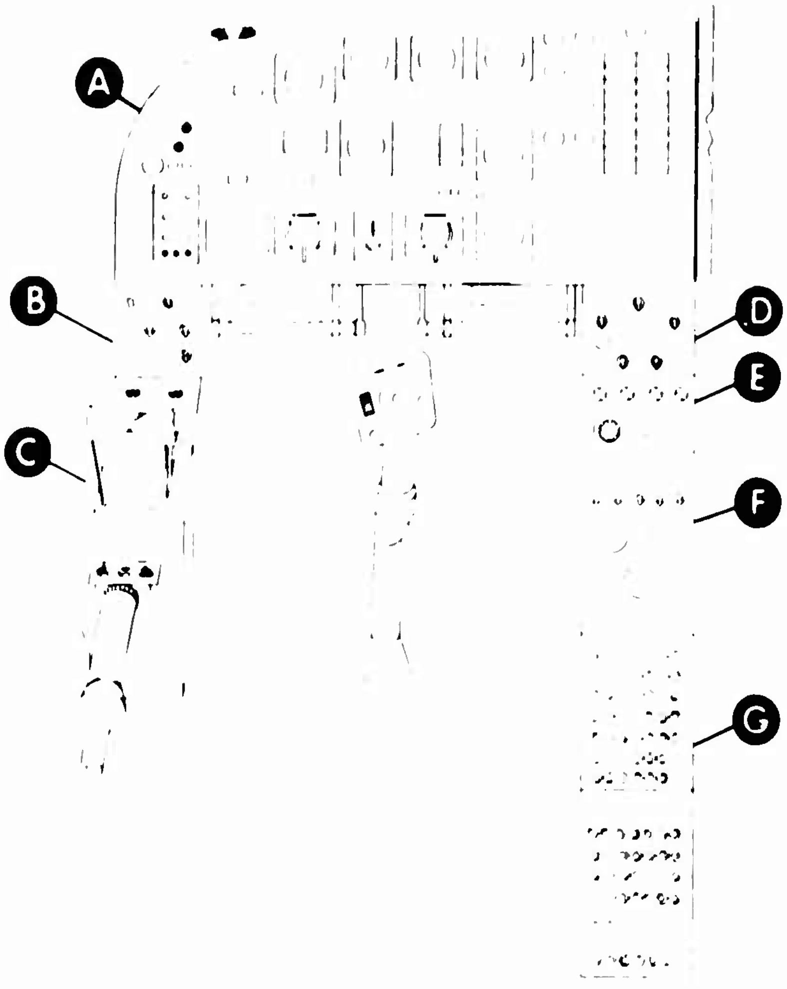
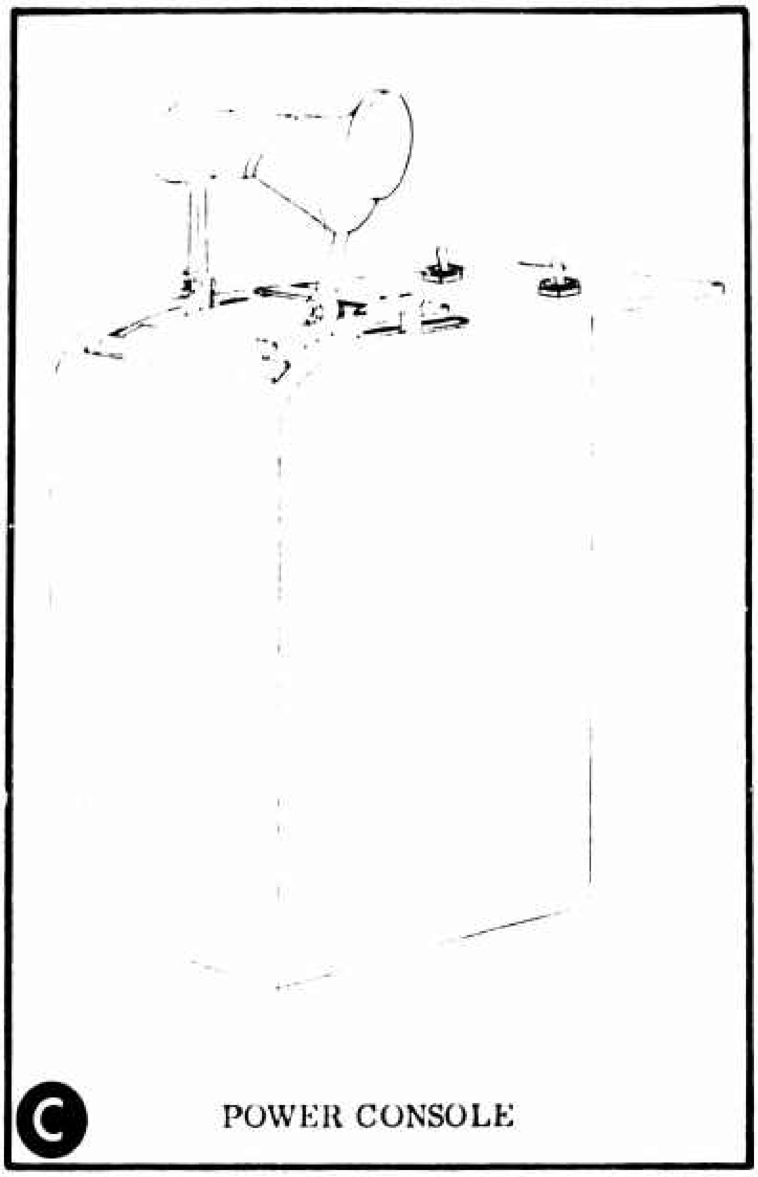
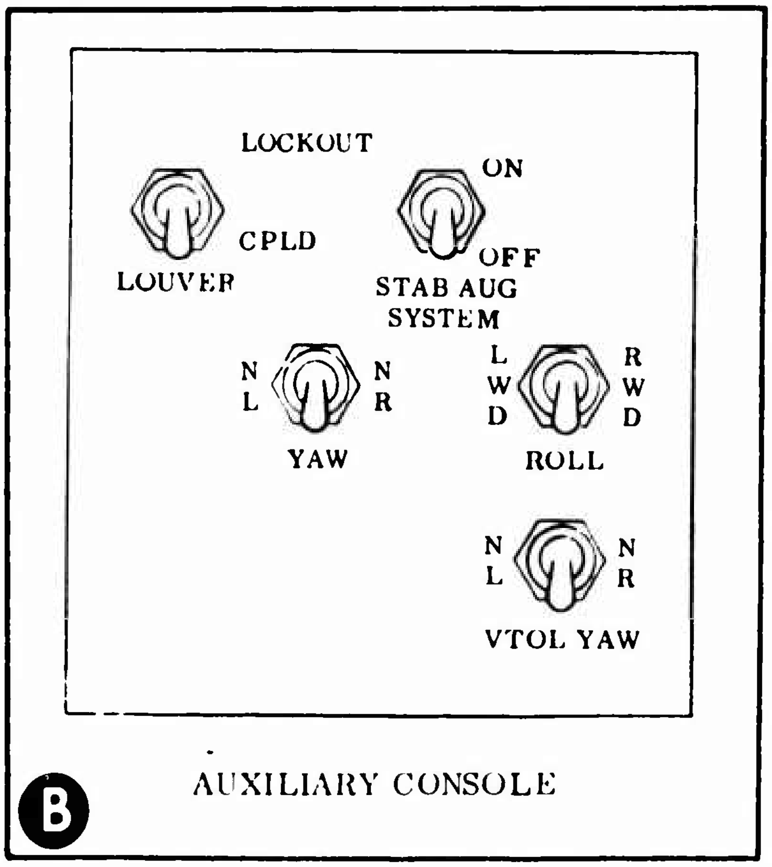


Figure 31 Aircraft Basic Structural Arrangement

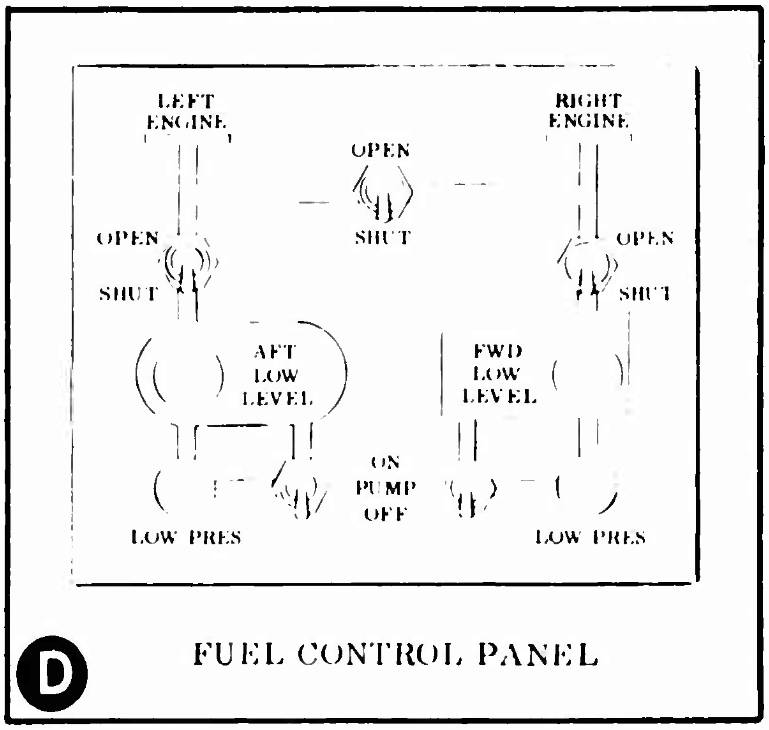




POWER CONSOLE

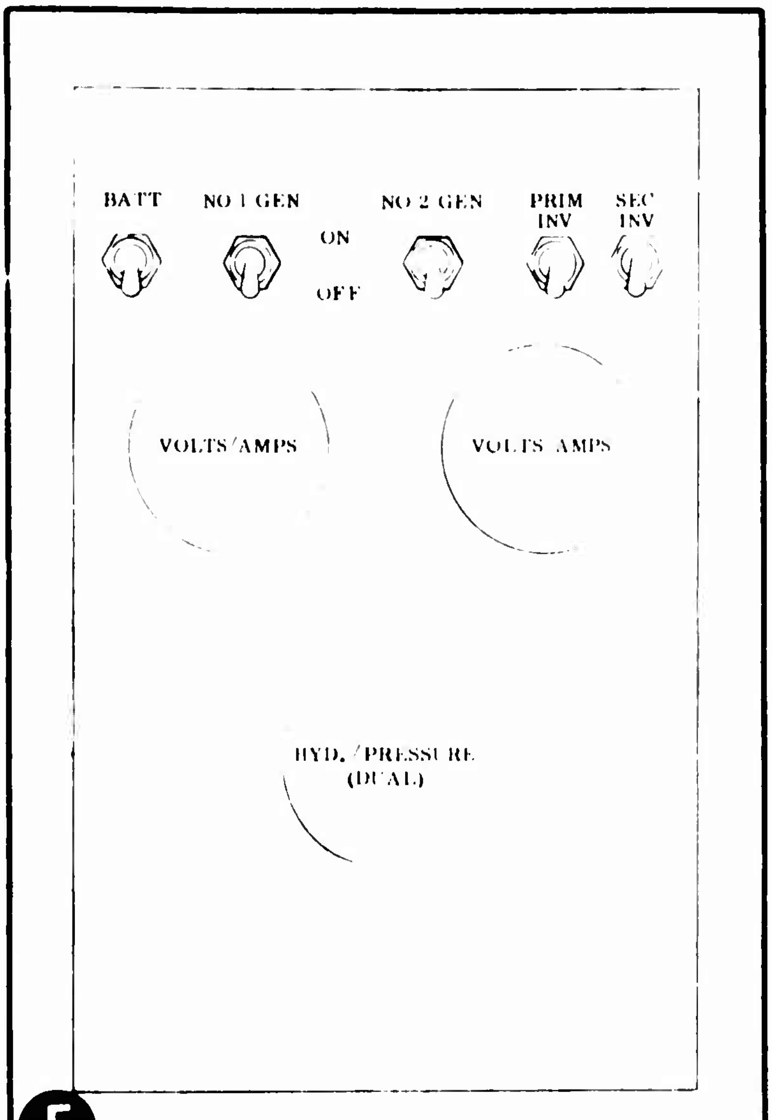


AUXILIARY CONSOLE

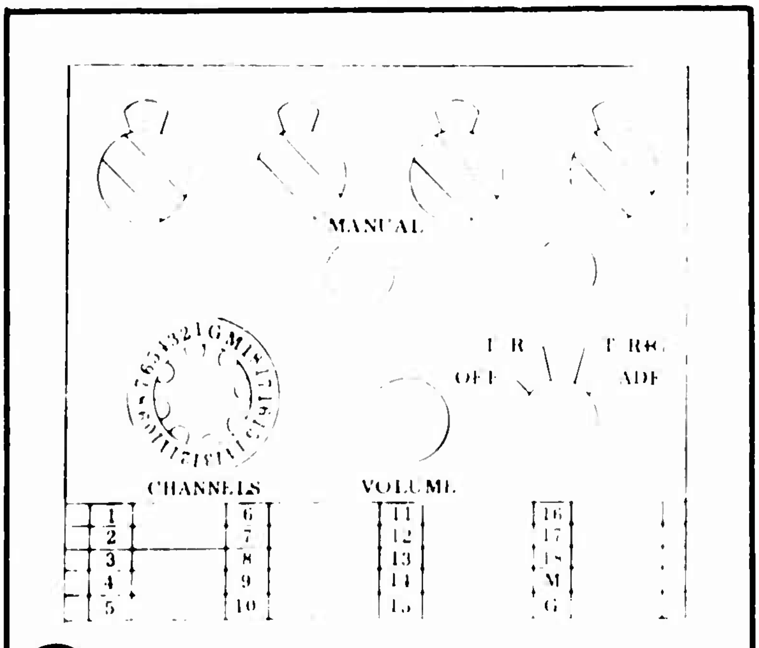


FUEL CONTROL PANEL

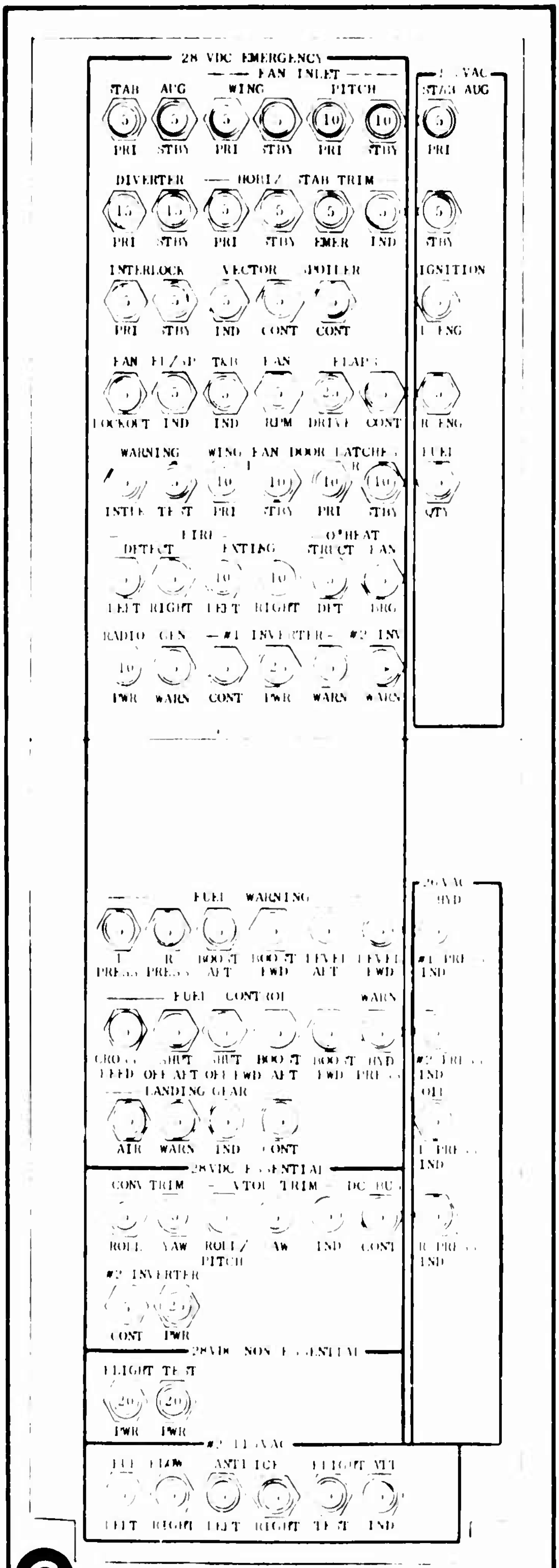
R-218-32



F ELECTRICAL PANEL



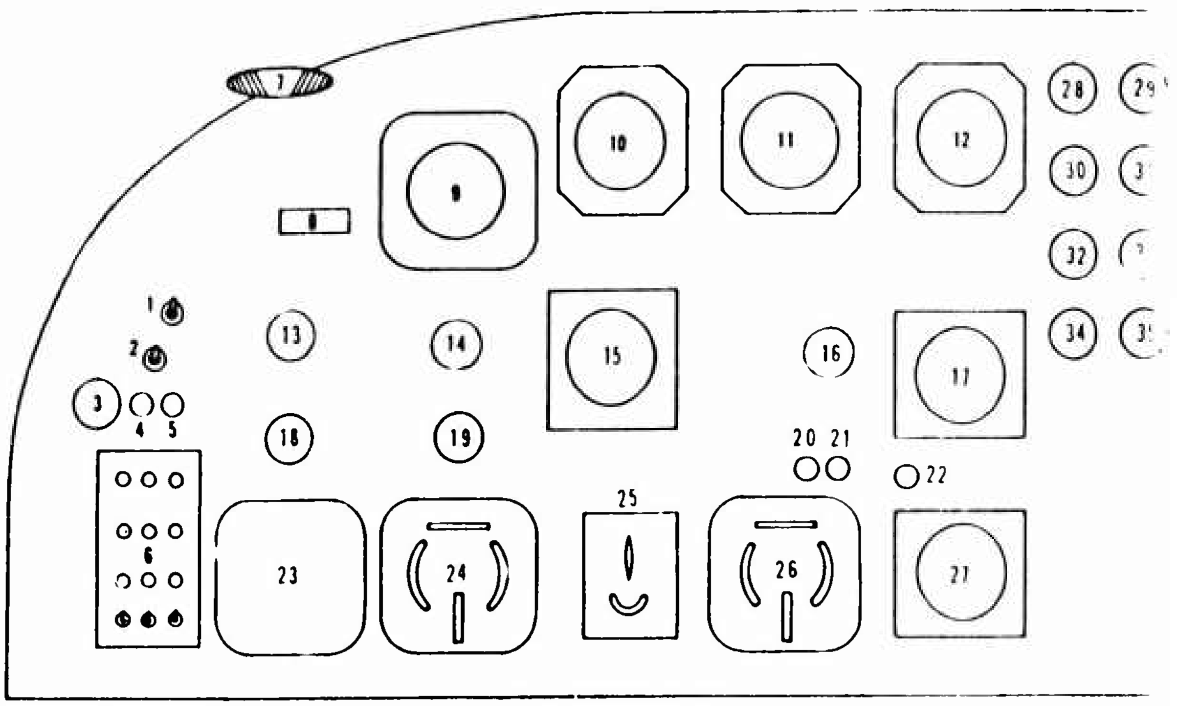
E UHF RADIO



G CIRCUIT BREAKER PANEL

B

A

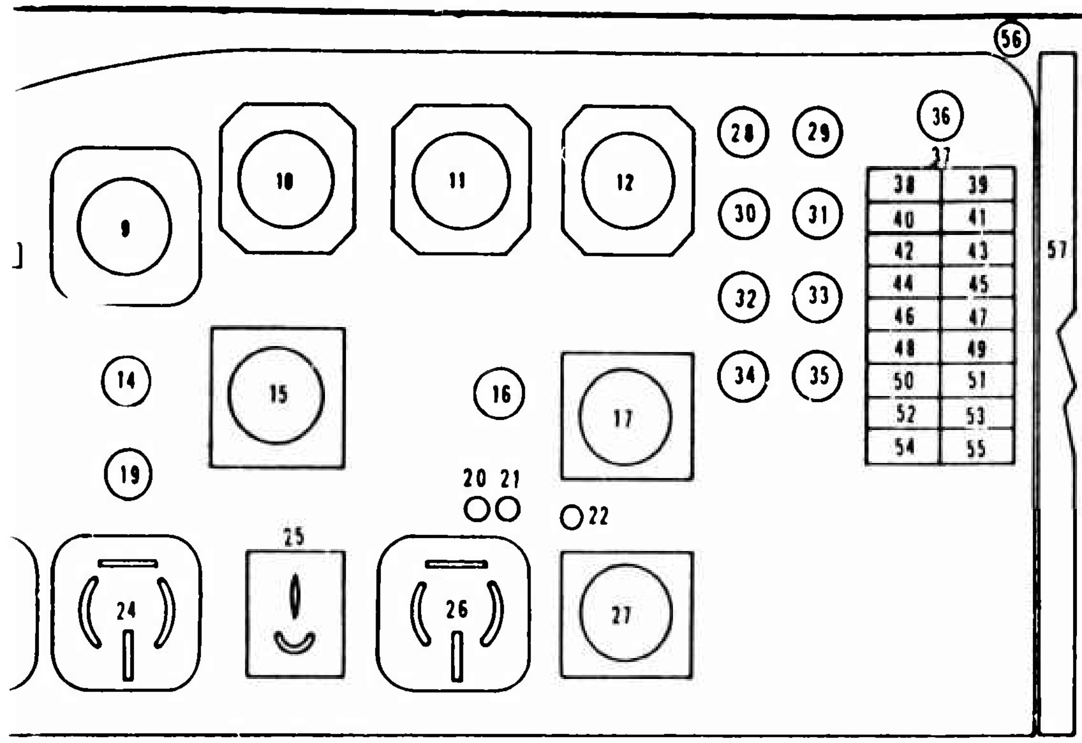


INSTRUMENT PANEL

1 EXTINGUISHING AGENT DISCHARGE SWITCH
2 EXTINGUISHING AGENT SELECTOR SWITCH
3 AUTO-STAB PRIMARY OR STANDBY INDICATOR
4 FIRE WARNING INDICATOR
5 FIRE WARNING INDICATOR
6 AUTO-STAB CONTROL PANEL
7 DRAG CHUTE LEVER
8 MASTER CAUTION INDICATOR
9 VERTICAL SPEED INDICATOR
10 AIRSPEED INDICATOR
11 MACH METER
12 ALTITUDE INDICATOR
13 FLAP AND THRUST SPOILER POSITION INDICATOR
14 VECTOR ANGLE INDICATOR
15 ATTITUDE INDICATOR
16 SIDE SLIP INDICATOR
17 "G" ACCELEROMETER
18 PITCH FAN TACHOMETER
19 ANGLE OF ATTACK INDICATOR
20 FAN DOOR "LOCKED" INDICATOR LIGHT
21 FAN DOOR "UNLOCKED" INDICATOR LIGHT
22 DIVERTER VALVE INDICATOR (FAN)
23 DUAL FAN SPEED TACHOMETERS (WINGS)
24 CTOL TRIM INDICATOR
25 TURN AND BANK INDICATOR
26 VTOL TRIM INDICATOR
27 CLOCK
28 LEFT ENGINE TACHOMETER
29 RIGHT ENGINE TACHOMETER
30 LEFT ENGINE EXHAUST
31 RIGHT ENGINE EXHAUST
32 LEFT ENGINE FUEL FL
33 RIGHT ENGINE FUEL F
34 FUEL QUANTITY GAUGE
35 DUAL OIL PRESSURE G
36 REAR SPAR TEMPERAT
37 ANNUNCIATOR PANEL
38 FAN OVERSPEED WARNI
39 FAN BEARING OVERHE
40 GENERATOR NO. 1 OFF
41 GENERATOR NO. 2 OFF
42 INVERTER NO. 1 OFF W
43 INVERTER NO. 2 OFF W
44 LANDING GEAR HYDRAU
45 NO. 2 HYDRAULIC SYST
46 LANDING GEAR EMERG
47 STRUCTURE OVERHEAT
48 NO. 1 ENGINE OIL PRES
49 NO. 2 ENGINE OIL PRES
50 NO. 1 BOOST PRESSURE
51 NO. 2 BOOST PRESSURE
52 HARDOVER AUTO-STAB
53 ENGINE ANTI-ICE WAR
54 INTERLOCKS "NO GO" W
55 SPARE
56 MAGNETIC COMPASS
57 BLANK PANEL

Figure 32 Crew S

C



INSTRUMENT PANEL

WITCH	30	LEFT ENGINE EXHAUST GAS TEMPERATURE GAUGE
WITCH	31	RIGHT ENGINE EXHAUST GAS TEMPERATURE GAUGE
NDICATOR	32	LEFT ENGINE FUEL FLOW INDICATOR
	33	RIGHT ENGINE FUEL FLOW INDICATOR
	34	FUEL QUANTITY GAUGE
	35	DUAL OIL PRESSURE GAUGE
	36	REAR SPAR TEMPERATURE GAUGE
	37	ANNUNCIATOR PANEL
	38	FAN OVERSPEED WARNING LIGHT
	39	FAN BEARING OVERHEAT WARNING LIGHT
	40	GENERATOR NO. 1 OFF WARNING LIGHT
	41	GENERATOR NO. 2 OFF WARNING LIGHT
ON INDICATOR	42	INVERTER NO. 1 OFF WARNING LIGHT
	43	INVERTER NO. 2 OFF WARNING LIGHT
	44	LANDING GEAR HYDRAULIC SYSTEM PRESSURE LOW WARNING LIGHT
	45	NO. 2 HYDRAULIC SYSTEM PRESSURE LOW WARNING LIGHT
	46	LANDING GEAR EMERGENCY AIR PRESSURE LOW WARNING LIGHT
	47	STRUCTURE OVERHEAT WARNING LIGHT
	48	NO. 1 ENGINE OIL PRESSURE LOW WARNING LIGHT
GHT	49	NO. 2 ENGINE OIL PRESSURE LOW WARNING LIGHT
LIGHT	50	NO. 1 BOOST PRESSURE LOW WARNING LIGHT
	51	NO. 2 BOOST PRESSURE LOW WARNING LIGHT
INGS)	52	HARDOVER AUTO-STAB FAILURE WARNING LIGHT
	53	ENGINE ANTI-ICE WARNING LIGHT
	54	INTERLOCKS "NO GO" WARNING LIGHT
	55	SPARE
	56	MAGNETIC COMPASS
	57	BLANK PANEL

Figure 32 Crew Station Arrangement Diagram

3.8.2.3 Casing and Tubes. - Each of the main gear installations shall be provided with one 20 x 4.4 by 12 PR nylon type, high pressure, tubeless tire. Tires shall comply with specification MIL-C-5041B.

3.8.2.4 Shock Absorbers. - The main landing gear strut shall be designed in accordance with specification MIL-S-8552A. Each strut shall be capable of absorbing the shock of a 10 FPS velocity vertical landing at design gross weight in the hover mode, and 10 FPS sink rate in the conventional flight mode, at basic design gross weight.

3.8.2.5 Retracting, Extending, and Locking Systems. - Gear retraction and extension shall be accomplished hydraulically by a folding set of drag links that mechanically lock the gear in the extended or retracted positions. Emergency provisions shall be made to lower the gear in event of hydraulic system pressure loss.

3.8.2.6 Doors and Fairings. - Wheel doors shall be mechanically actuated and shall close only when the gear is retracted.

3.8.2.7 Inspection and Maintenance. - Provisions for inspection and maintenance of the installed main landing gear shall be included.

3.8.3 Auxiliary Landing Gear (Tail Wheel). - Not applicable.

3.8.4 Auxiliary Landing Gear (Nose Wheel). -

3.8.4.1 Description. - The nose gear assembly shall consist of a shock strut with single fork-type axle and wheel assembly (see Figure 33). The gear assembly shall be attached to the fuselage structure with trunnion fittings. The gear assembly shall lock in the extended or retracted positions. Emergency provisions shall be incorporated for gear extension in case of hydraulic system pressure loss. A nose wheel shimmy damper shall be provided. Steerable nose wheel provisions shall not be included.

3.8.4.2 Wheels. - The nose landing gear wheel shall be 18 x 4.4 and shall comply with specification MIL-W-5013E. The wheel shall be capable of rolling under maximum forward C.G. conditions for a minimum of 1000 miles.

3.8.4.3 Casings and Tubes. - The nose gear installation shall be provided with one 18 x 4.4 by 10 PR nylon, type VII, high pressure, tubeless tire in accordance with specification MIL-C-5041B.

3.8.4.4 Shock Absorbers. - The nose gear shock strut shall be designed in accordance with specification MIL-S-8552A.

3.8.4.5 Retracting, Extending, and Locking Systems. - Nose gear extension and retraction shall be accomplished hydraulically by a folding set of drag links

which lock the gear in the extended or retracted positions. Positive lock provisions shall be included in event of hydraulic pressure loss. Emergency extension provisions shall be included.

3.8.4.6 Doors and Fairings. - Wheel doors shall be mechanically linked to landing gear operation.

3.8.4.7 Steering Control. - Nose wheel steering shall not be provided.

3.8.4.8 Inspection and Maintenance. - Provisions shall be included for inspection and maintenance of the installed nose gear assembly.

3.9 Alighting Gear (Water Type). - Not applicable.

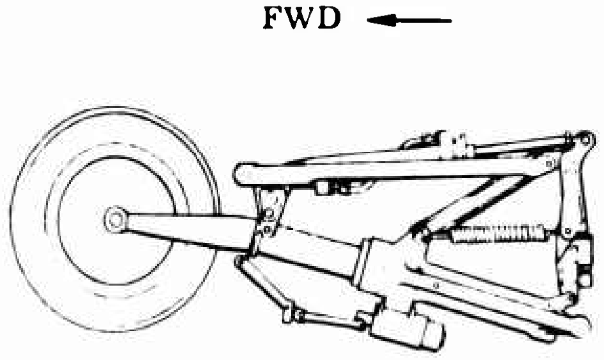
3.10 Flight Control System. -

3.10.1 Primary Flight Control Systems. - The primary flight control system (see Figure 34) shall consist of conventional stick and rudder pedals mechanically connected to aerodynamic flap-type control surfaces, wing-fan exit louvers, and a nose-fan thrust modulator hydraulic servo valve. Ailerons, wing-fan exit louvers and nose-fan thrust modulators shall be hydraulically actuated. Actuation of wing-fan louvers shall be accomplished using two actuators per fan (1 forward, 1 aft) to perform both vector and stagger functions, using an even-odd louver actuation scheme. Nose-fan thrust modulation shall be accomplished with one actuator. Wing-fan exit louver and nose-fan thrust modulator actuator servo valves shall have electrical input features capable of accepting actuator position input signals from the stability augmentation system amplifiers. The servo system shall be powered by two separate engine driven hydraulic systems. All hydraulic actuators shall be dual-tandem types. Stick and rudder pedals shall perform identical attitude control functions in the conventional and fan flight modes. A collective lift control shall be provided for altitude control in the fan flight mode. The collective lift control shall adjust wing-fan exit louver stagger, and nose-fan thrust modulator. Lateral stick motion shall control ailerons and differential stagger of wing-fan exit louvers. Longitudinal stick motion shall control elevators and nose-fan thrust modulators. Rudder pedals shall control the rudder and differential vector of the wing-fan exit louvers, and also the wheel brakes. A mechanical mixer mechanism shall be installed in series with the cockpit controls and louver actuator servo valves. The mixer shall be capable of interpreting pilot commands in positioning of the wing-fan exit louvers. The mixer shall provide a wing-fan control system disengagement feature for operation in the conventional flight mode. A similar device shall disengage the nose-fan thrust modulators. Devices shall be provided for trimming of the fan and aerodynamic control systems in flight. VTOL mode control power and sensitivity shall be adjustable. (Description in Appendix A)

3.10.1.1 Flight Station Controls. - All flight controls shall be arranged within the cockpit to provide maximum utility for flight evaluation of the aircraft, and comfort to the pilot. The flight controls, their functions, and locations are shown in Figure 35.

NOSE LANDING (

1. NLG HYDRAULIC A
2. NLG LOCKED SWI'I
3. JURY BRACE
4. SPRING
5. SHOCK STRUT
6. NLG WHEEL ASSE
7. SHIMMY DAMPER
8. GROUND LOCK P.
9. TORQUE LINKS
10. UPPER DRAG BRA
11. LOWER DRAG BR.



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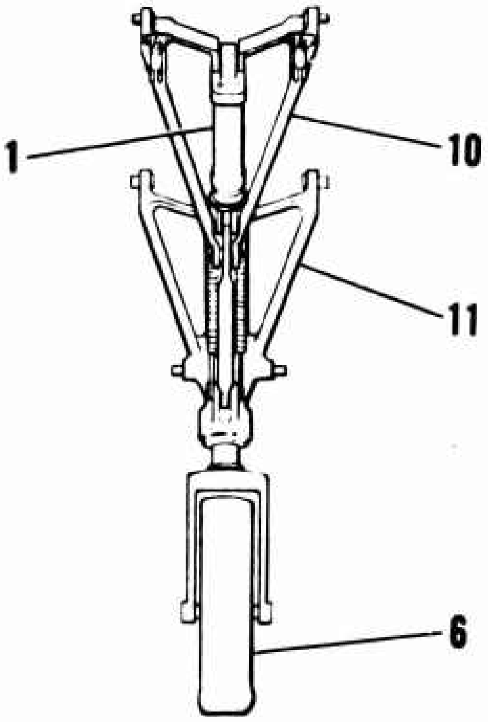
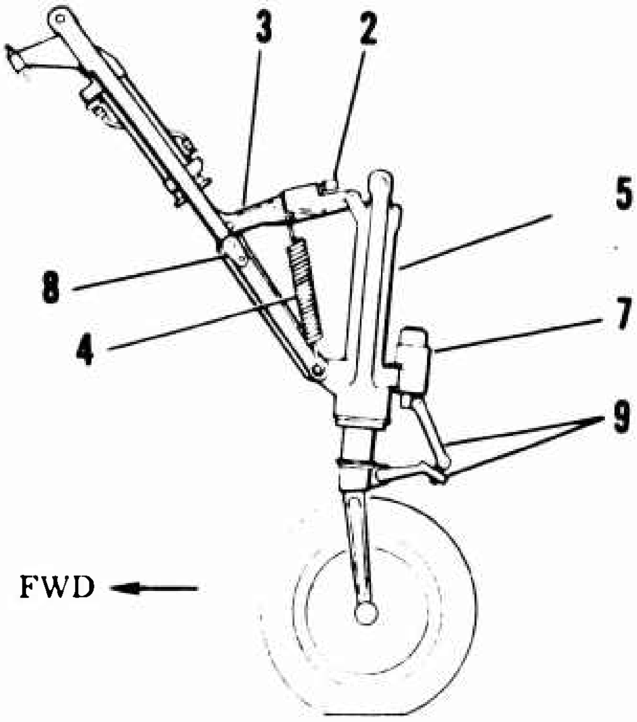
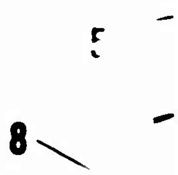


FRONT VIEW



SIDE VIEW

NOSE LANDING GEAR



R-210-33

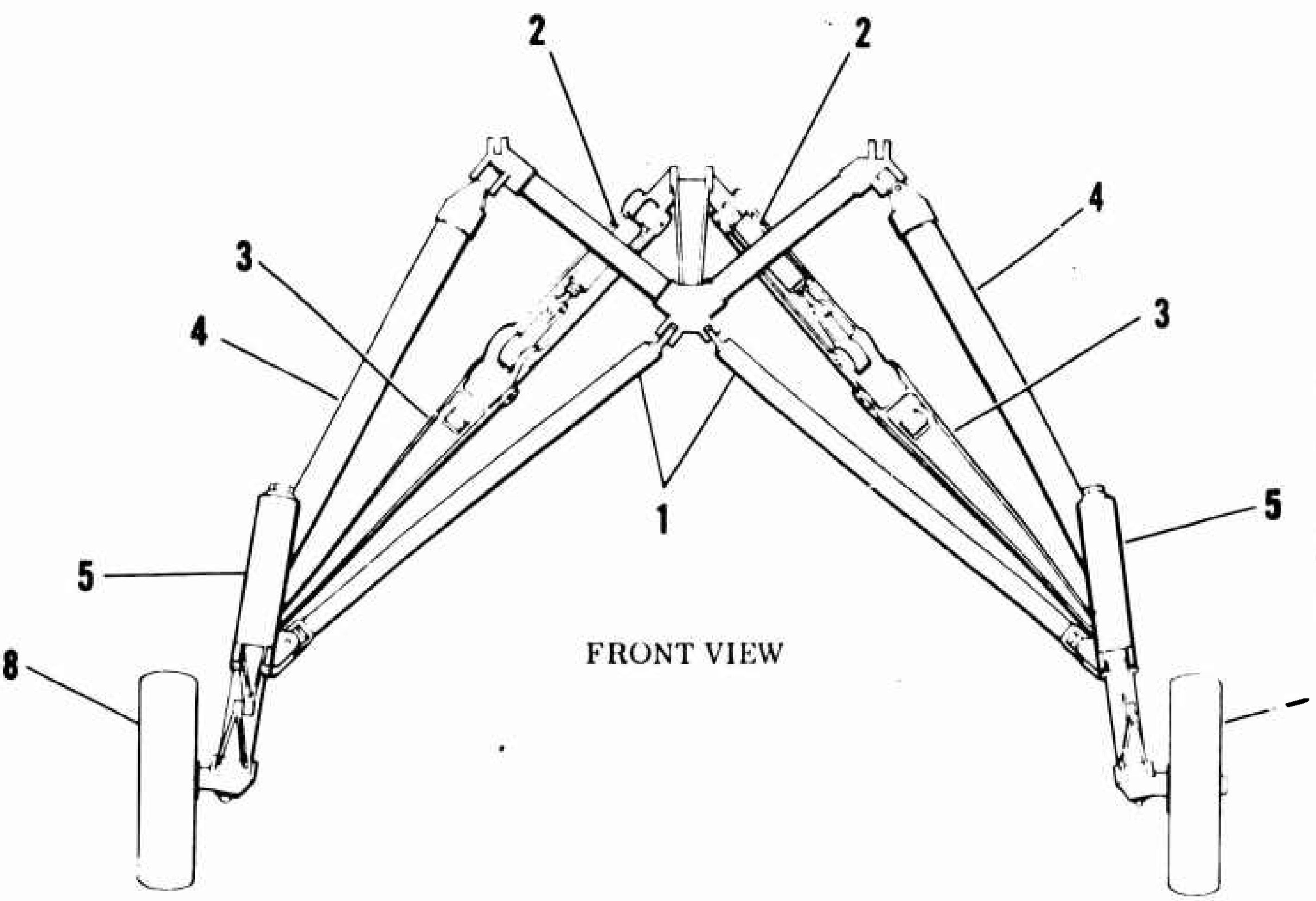
A

NOSE LANDING GEAR

1. NLG HYDRAULIC ACTUATOR
2. NLG LOCKED SWITCH
3. JURY BRACE
4. SPRING
5. SHOCK STRUT
6. NLG WHEEL ASSEMBLY
7. SHIMMY DAMPER
8. GROUND LOCK PIN
9. TORQUE LINKS
10. UPPER DRAG BRACE
11. LOWER DRAG BRACE

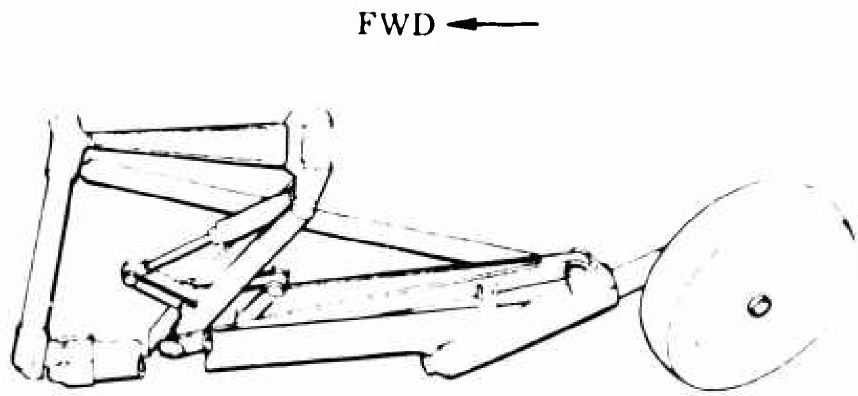
MAIN LANDING GEAR

1. SIDE SWAY BRACE
2. MLG HYDRAULIC ACTUATOR
3. DRAG STRUT ASSEMBLY
4. MAIN SUPPORT STRUT
5. SHOCK STRUT
6. TORQUE LINK
7. MLG FOLD MECHANISM
8. MLG WHEEL AND BRAKE ASSEMBLY



FRONT VIEW

B



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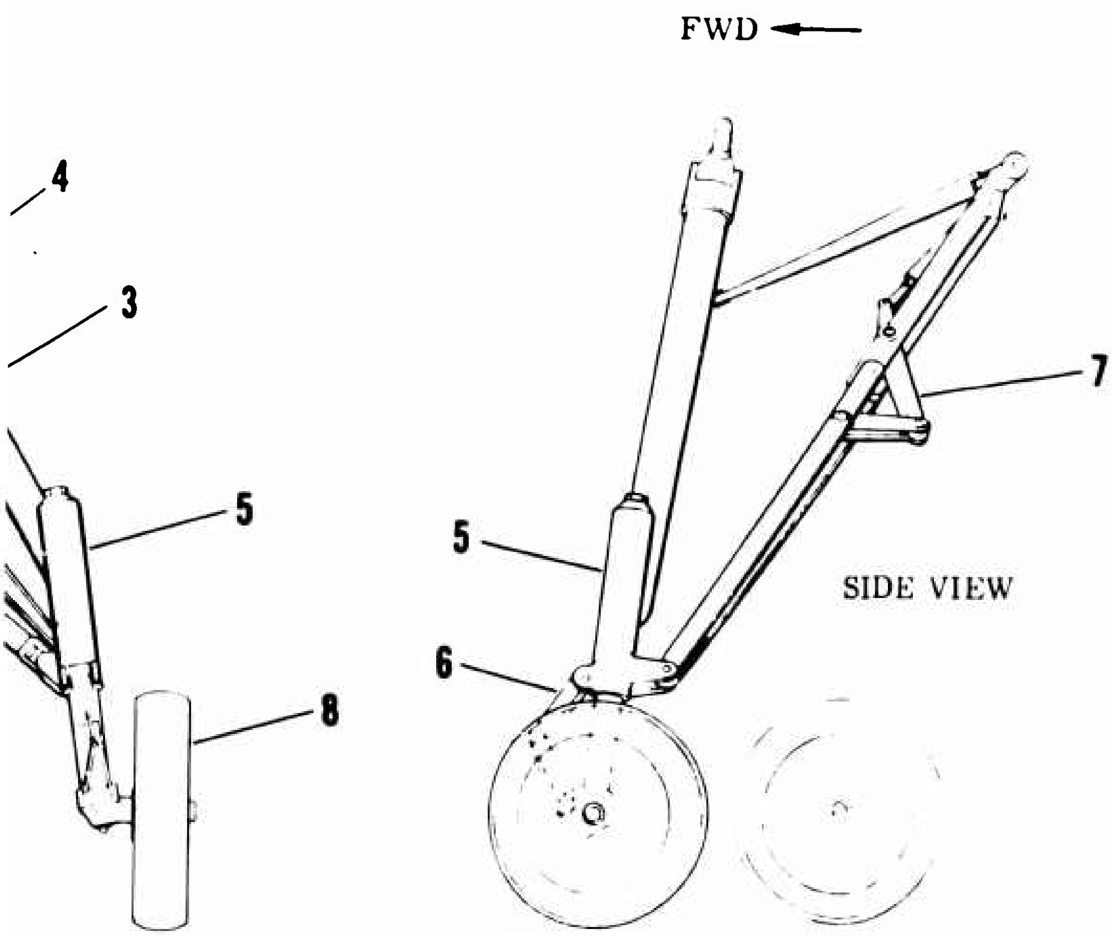


CTOL & STOL POSITION

VTOL POSITION

MAIN LANDING GEAR

Figure 33 Aircraft Landing Gear Configuration

C

3.10.1.2 Lateral System. - The lateral (roll) system shall utilize ailerons, and differential stagger (Figure 36) of the wing-fan exit louver system. Aileron actuation shall be accomplished using a hydraulic servo system. Differential stagger shall be controlled by a hydraulic servo system. The lateral control system shall be actuated by the pilot through the use of push rods and bellcranks. Pilot commands shall pass through a mechanical mixing mechanism yielding a control signal to the forward and aft louver actuators. In conventional flight, pilot control forces shall be obtained from adjustable geared trailing edge tabs. The geared tabs shall incorporate mass balance. In the fan flight mode, artificial force feel with stick centering shall be provided. In the conventional flight mode, the fan mode control is disengaged at the mixer.

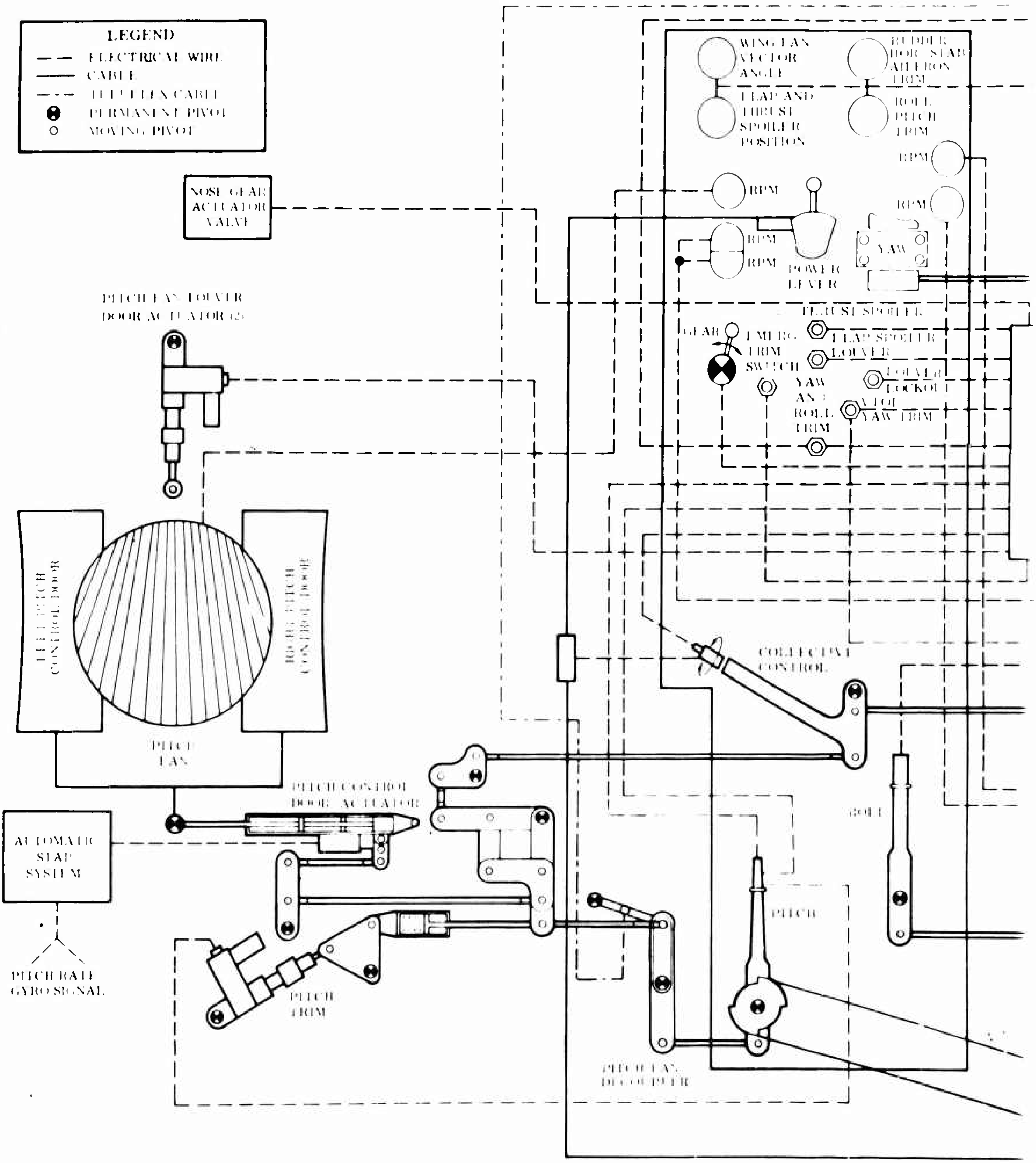
3.10.1.3 Directional System. - The directional (yaw) system shall utilize a rudder and differential vector (Figure 36) of the wing fan exit louver system. Rudder actuation shall be accomplished using a push-rod cable system with a tension regulating cable drum. Differential vector shall be controlled by a hydraulic servo system. The system shall be mechanically actuated by the pilot through the use of push rods and bellcranks. Pilot commands shall pass through a mechanical mixing mechanism yielding a control signal to the forward and aft louver actuators. The rudder shall incorporate mass balance. In the fan flight mode, an artificial rudder force gradient shall be provided. In conventional flight mode, fan mode control is disengaged at the mixer.

3.10.1.4 Longitudinal System. - The longitudinal (pitch) system shall utilize an elevator and nose-fan thrust modulation mechanism (Figure 36). Elevator actuation shall be accomplished using a push-rod cable system with a tension regulating cable drum. The nose fan thrust modulator shall be controlled by a hydraulic servo system. The system shall be mechanically actuated by the pilot through the use of a push-rod and bellcrank system. Pilot inputs shall pass through a mechanical mixing mechanism which sums the pitch and collective stagger altitude control commands. The elevator shall incorporate mass balance. In fan flight mode, an elevator force gradient with stick centering shall be provided. For conventional flight, fan mode control is disengaged at the mixer.

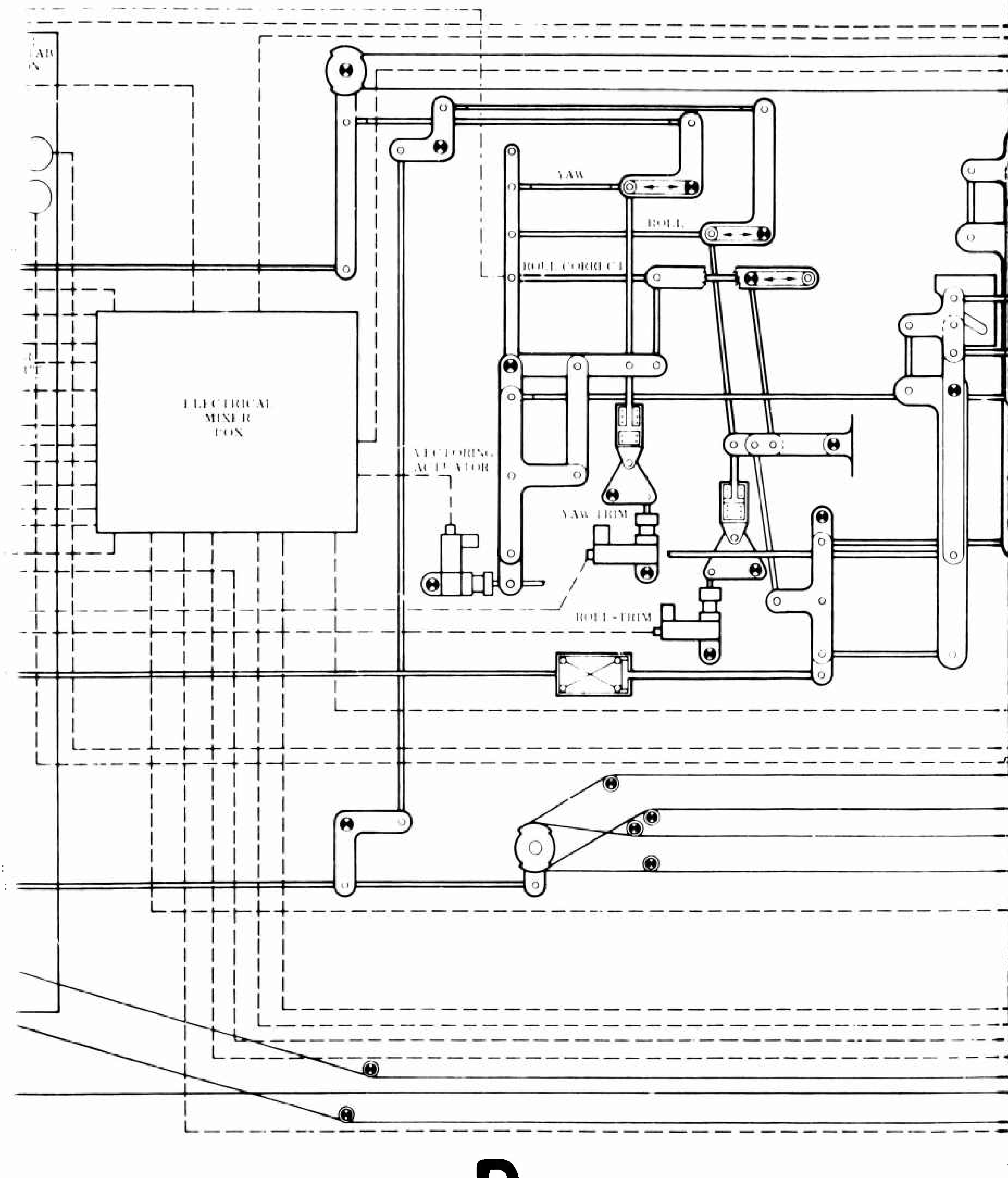
3.10.1.5 Lift System. - The lift (altitude) system shall utilize collective stagger of the wing-fan exit louver system and the nose-fan thrust modulator mechanism (Figure 36). Control shall be accomplished by a hydraulic servo system. The system shall be mechanically actuated by the pilot through the use of push-rods and bellcranks connected to servo valves. Pilot commands shall pass through a mechanical mixing mechanism yielding control signals to the wing fan louver actuators and the nose-fan modulator actuators. In the conventional flight mode, the lift control system is disengaged at the mixer. The collective lift control shall be irreversible.

3.10.2 Secondary Flight Control Systems. -

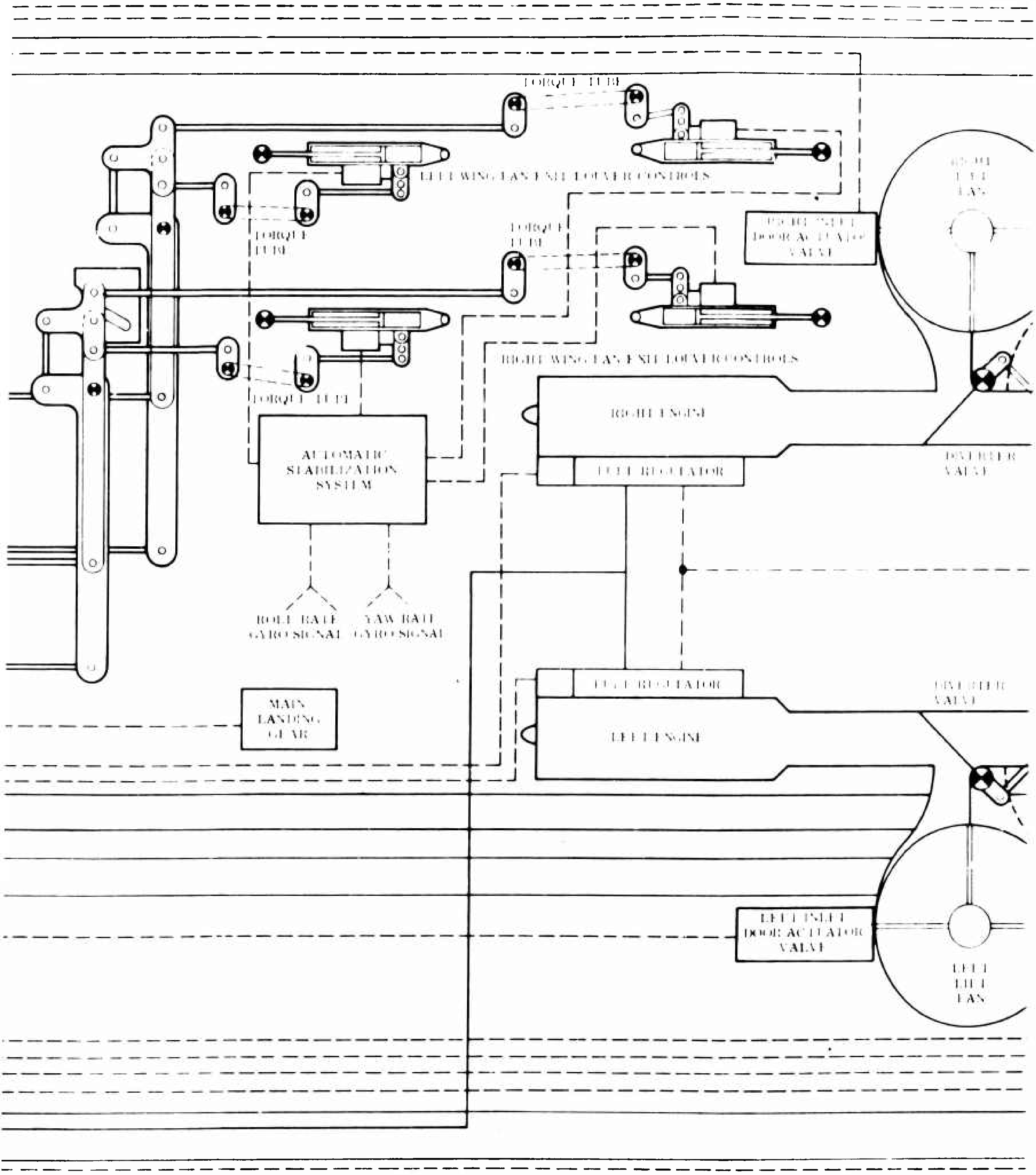
3.10.2.1 Lift and Drag Increasing Device Systems. - Single-slotted flaps shall be incorporated, and controlled by pilot command. Symmetrical aileron deflection shall


LEGEND
ELECTRICAL WIRE
CABLE
PERMANENT PIVOT
MOVING PIVOT
NOSE GEAR ACTUATOR VALVE
WING FAN VECTOR ANGLE
FLAP AND THRUST SPOILER POSITION
ROLL PITCH TRIM
RPM
RPM
RPM
RPM
RPM
POWER LEVER
YAW
THRUST SPOILER
FLAP SPOILER
LOUVER
LOCKOUT
GEAR
EMERG TRIM SWITCH
YAW AND ROLL TRIM
VTOL YAW TRIM
PITCH FAN
PITCH CONTROL DOOR ACTUATOR
AUTOMATIC STAB SYSTEM
PITCH RATE GYRO SIGNAL
PITCH TRIM
COLLECTIVE CONTROL
ROLL
PITCH
PITCH FAN DECOUPLER

A


YAW
ROLL
ROLL CORRECT
ELECTRICAL
MIXER
BOX
VECTORING
ACTUATOR
YAW TRIM
ROLL TRIM

B


TORQUE TUBE
LEFT WING FAN EXIT LOUVER CONTROLS
TORQUE TUBE
TORQUE TUBE
RIGHT INLET DOOR ACTUATOR VALVE
RIGHT WING FAN EXIT LOUVER CONTROLS
TORQUE TUBE
RIGHT ENGINE
AUTOMATIC STABILIZATION SYSTEM
DIVERTER VALVE
FUEL REGULATOR
ROLL RATE GYRO SIGNAL
YAW RATE GYRO SIGNAL
FUEL REGULATOR
DIVERTER VALVE
MAIN LANDING GEAR
LEFT ENGINE
LEFT INLET DOOR ACTUATOR VALVE
LEFT LIFT FAN

C

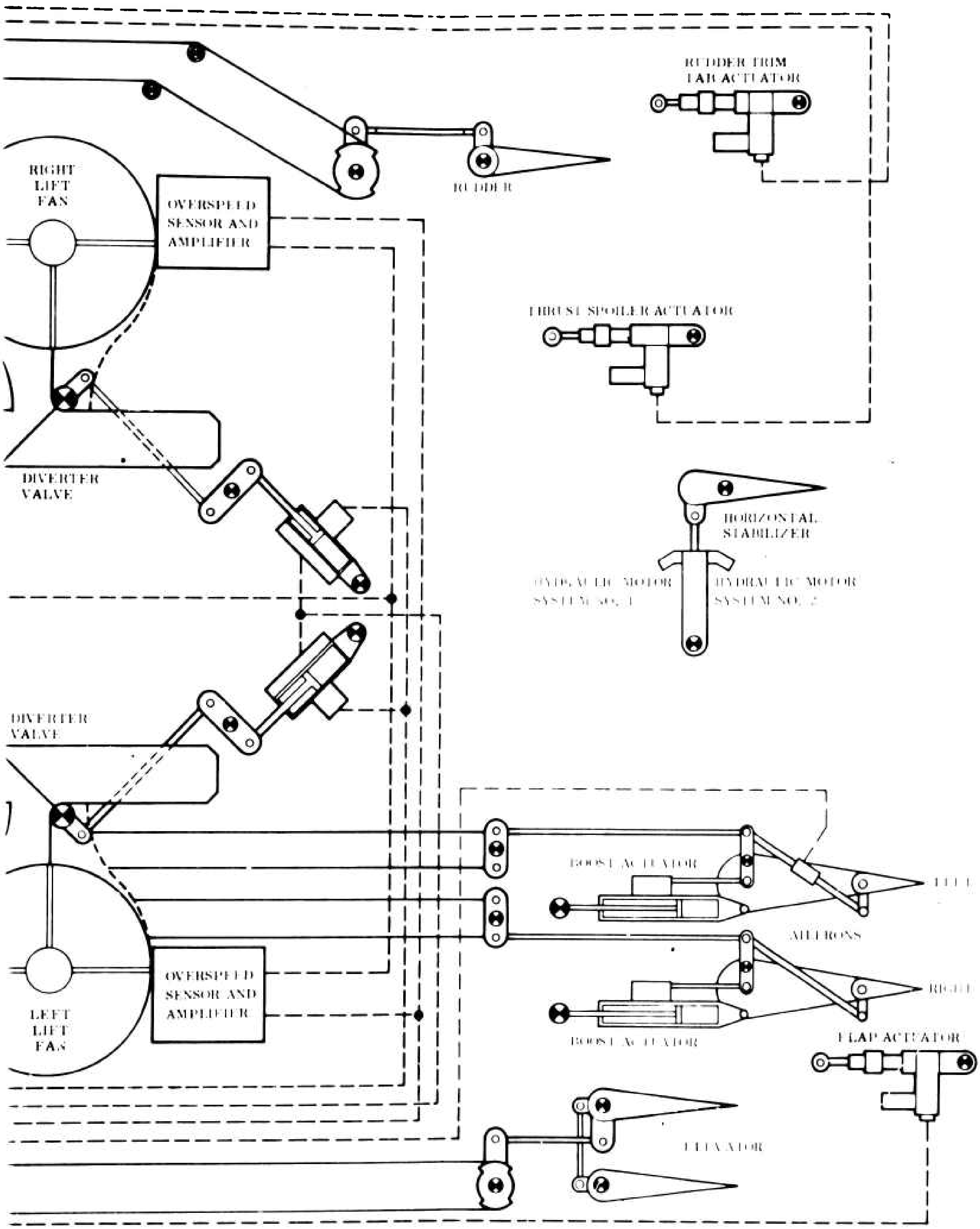
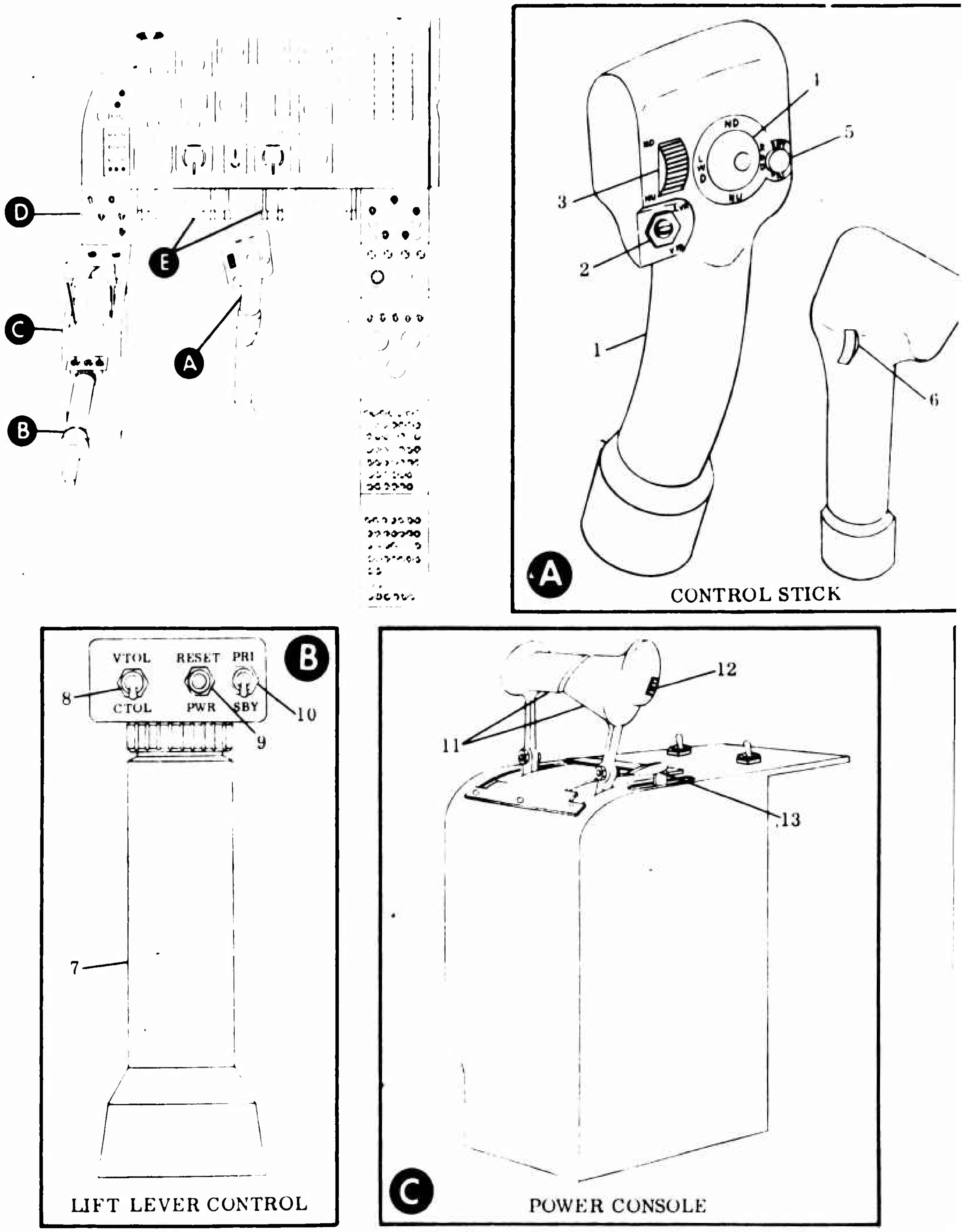
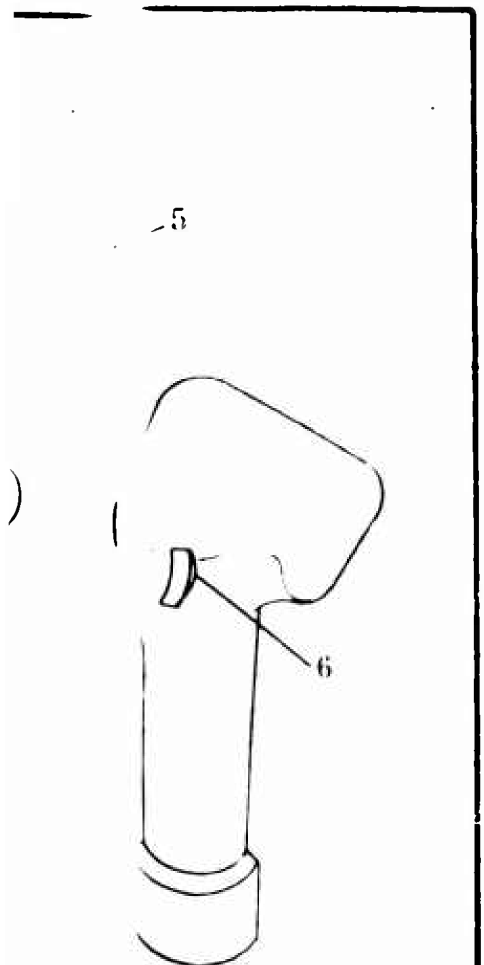


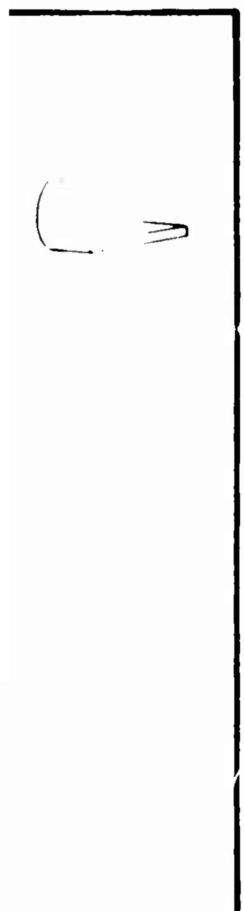
Figure 34 Flight Control System Schematic Diagram

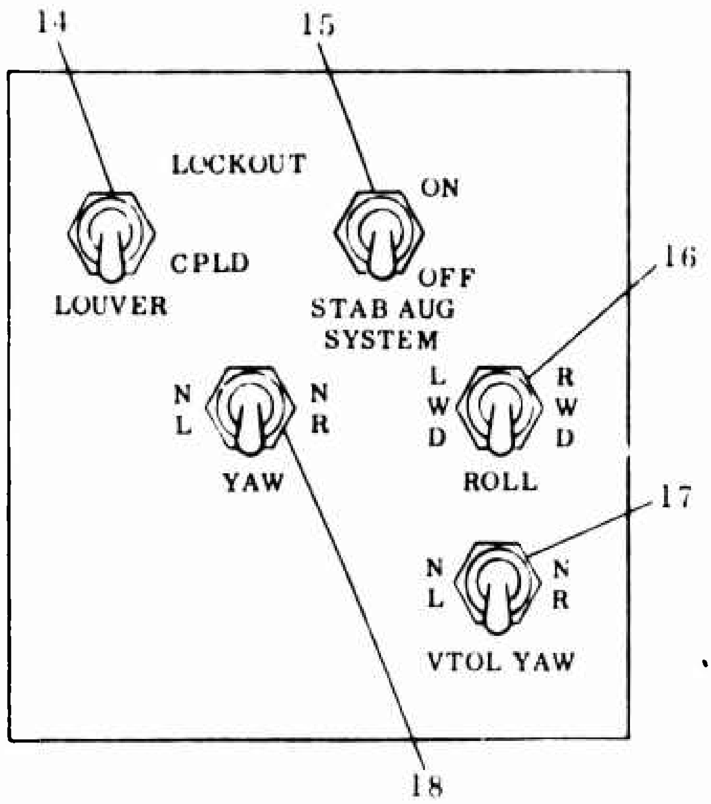

D
E
C
A
B
1
5
3
2
1
6
CONTROL STICK
VTOL
RESET
PRI
CTOL
PWR
SBY
8
9
10
7
LIFT LEVER CONTROL
12
11
13
POWER CONSOLE

A 218 35

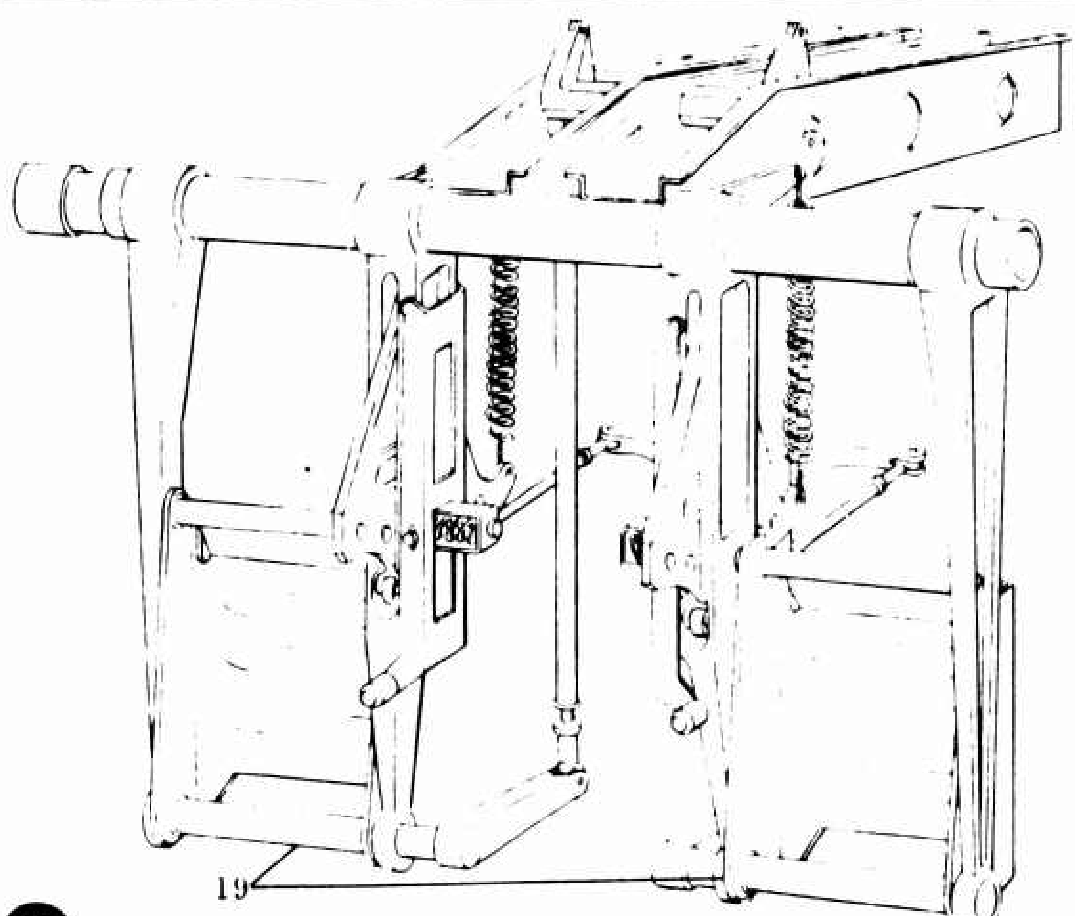
A







D AUXILIARY CONSOLE



E RUDDER PEDALS

E

B

Control		Fan Mode	Conventional Mode
1	Longitudinal Stick (pitch)	Controls nose fan thrust modulator doors	Positions elevator
1	Lateral Stick (roll)	Controls differential wing-fan exit louver stagger	Positions ailerons
2	Exit louver vector selector	Commands exit louver deflection	Inoperative
3	Conventional pitch trim	Operative as in conventional mode	Positions horizontal stabilizer
4	Hovering roll-pitch trim	Adjusts centering devices for position of the stick for zero force in hovering	Inoperative
5	Stability Augmentation System primary-standby switch	Commands selection of the primary or standby stability augmentation systems	Inoperative
6	Microphone button	Operative as in conventional mode	Authority for air-ground or air-air communication
7	Collective Lift (altitude)	Controls collective wing-fan exit louver stagger and nose fan thrust modulator doors	Inoperative
7	Collective Power	Controls gas generator speeds collectively	Operative as in fan mode
8	Mode Selector	Commands conversion to conventional flight	Commands conversio to fan flight
9	Power Reset	Commands return to original gas generator power setting following automatic cutback as a result of fan overspeed	Inoperative
10	Electrical System primary-standby switch	Operative as in conventional mode	Commands selection of the primary or standby electrical sy
11	Power Levers	Operative as in conventional mode	Controls gas generat speeds independently

C

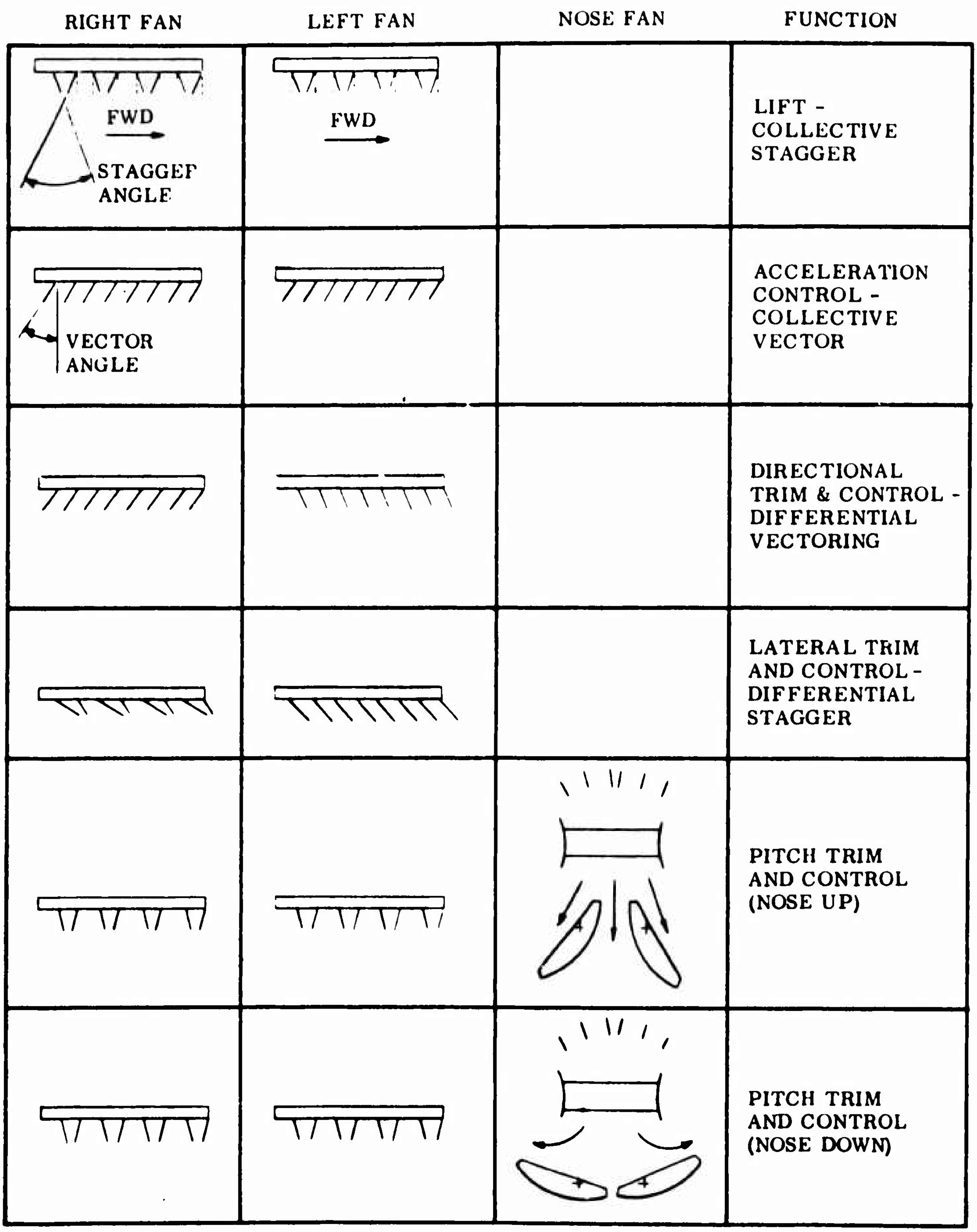
	Conventional Mode
fan tor doors	Positions elevator
rential louver	Positions ailerons
it louver	Inoperative
in conventional	Positions horizontal stabilizer
ring devices for e stick for zero ring	Inoperative
lection of the tandby stability systems	Inoperative
in conventional	Authority for air-ground or air-air communication
ective wing-fan tagger and nose odulator doors	Inoperative
generator tively	Operative as in fan mode
onversion to flight	Commands conversion to fan flight
eturn to original r power setting omatic cutback f fan overspeed	Inoperative
in conventional	Commands selection of the primary or standby electrical system
in conventional	Controls gas generator speeds independently

	Control
12	Thrust spoiler control
13	Flap-Closure control
14	Closure control lockout
15	Stability Augmentation System on-off control
16	Conventional roll trim
17	Hovering yaw trim
18	Conventional yaw trim
19	Rudder Pedals

Fan Mode	Control	Fan Mode	Conventional Mode
Operative a mode	Thrust spoiler control	Operative as in conventional mode	Commands thrust spoiler position
Operative a mode with function re	Flap-Closure control	Operative as in conventional mode with closure command function removed	Authority for simultaneous command of flap deflection, nose fan inlet doors and thrust modulating doors, and wing fan exit louvers
Inoperative	Closure control lockout	Inoperative	Authority for engagement and disengagement with Flap-Closure control and separate command of nose fan inlet doors and thrust modulating doors, and wing fan exit louvers
Commands system on	Stability Augmentation System on-off control	Commands stability augmentation system on or off	Inoperative
Operative a mode	Conventional roll trim	Operative as in conventional mode	Adjusts aileron trim tab
Adjusts cen position of for zero fo	Hovering yaw trim	Adjusts centering devices for position of the rudder pedals for zero force in hovering	Inoperative
Operative a mode	Conventional yaw trim	Operative as in conventional mode	Adjusts rudder trim tab
Controls di exit louver	Rudder Pedals	Controls differential wing fan exit louver vectoring	Positions rudder

Figure

Figure 35 Flight Station Controls



R-218-36

Figure 36 VTOL Flight Control System Operation

also be provided and programed automatically with flap deflection. Flaps shall be interlocked to prevent selection of VTOL and STOL flight modes unless they are in the full down position. The flaps shall have provisions for positioning at intermediate points during conventional flight. A cockpit indicator shall be provided for flap position information. A thrust spoiler device shall be included to permit high gas producer output with low forward thrust component, to reduce fan spin-up time during conversion from conventional to fan flight. An anti-spin and drag parachute installation shall be provided.

3.10.2.2 Speed Brakes. - Not applicable

3.10.3 Trim Control Systems. - Lateral and directional aerodynamic trim shall be accomplished by use of electrical screw jacks located in the tab system. Longitudinal aerodynamic trim shall be accomplished by a hydraulically driven screw jack attached to the horizontal stabilizer. Hovering flight trim shall be accomplished by adjustment of stick and rudder pedal positions for zero forces. Longitudinal trim for transition shall be accomplished by pre-setting horizontal stabilizer incidence as a function of stick displacement from neutral. Nose fan thrust modulator neutral stick position and authority is a function of exit louver position.

3.10.4 Automatic Flight Control System. - Automatic flight control shall not be provided. A stability augmentation system shall be provided for fan supported flight. See paragraph 3.3.2.1.1.

3.10.5 Conversion Interlock System. - The aircraft shall include an electrical interlock control system to provide proper succession of conversion steps.

3.11 Engine Section or Nacelle Group. -

3.11.1 Description and Components. - Two General Electric J-85-5 turbojet engines with diverter valves shall be located above the wing, and aft of the crew station. The engines shall be mounted side-by-side in a common nacelle isolated by vertical and horizontal firewalls. The engines shall have a common induction inlet with an internal flow splitter. The inlet is located above and aft of the canopy. Engine access doors shall be removable to permit simultaneous servicing of the engines. Engine induction inlets shall be removable for servicing engine controls.

3.11.2 Construction. - The engine access panels shall be an integral part of the fuselage structure but shall not contain any primary load-carrying structures. Material shall be aluminum alloy with honeycomb construction with exception of the firewalls. Air induction inlets shall be made of reinforced fiberglas.

3.11.3 Engine Mounts. - The engine mounting system (see Figure 37) shall consist of master mounts at the diverter valves, and vertical mounts at the forward end of the engines. Side mounts shall be provided at the lower, forward section of the diverter valves.

3.11.3.1 The wing fan mounting system (see Figure 37) shall consist of three mounts for each fan. A forward master mount attached to the forward wing spar shall be provided. This mount shall be a ball and socket type capable of accepting reaction loads in all directions. An inboard side mount shall be provided at the span-wise center line of the fuselage. This mount shall be capable of accepting reaction loads in the vertical, fore, and aft planes. An aft fan mount shall be provided and attached to the aft wing spar. This mount shall be capable of accepting reaction loads in the vertical and lateral planes. The fan-surrounding wing structure shall terminate in a circular seal of flexible material. The seal shall attach to the wing structure and fan frame, sealing the wing surface and permitting fan movement relative to the wing.

3.11.3.2 The nose fan mounting system (see Figure 37) shall consist of a master mount located at the aft section of the fan and attached to a cantilever trussed structure. Two side fan mounts shall be provided and attached to fuselage longerons.

3.11.4 Vibration Isolators. - Vibration isolators shall not be required.

3.11.5 Firewalls. - Engine compartment front, bottom, and aft end shall incorporate fire isolation provisions. The engine compartment shall be sealed at the forward and aft ends by vertical titanium firewalls. A horizontal firewall shall seal the bottom of the engine compartment. This firewall shall be made of titanium and shall contain holes to accommodate the diverter valves and engine starter lines. Finger seals shall be used to seal holes around the diverter valves and engine starter lines. The engines shall be isolated from each other by a vertical titanium firewall that runs the length of the engine compartment. The top of the vertical firewall shall be sealed to the engine compartment top panel with a fire resistant seal. A vertical firewall shall be included to isolate each engine burner section from its compressor section.

3.12 Propulsion Subsystem. -

3.12.1 General Description and Components. - Two General Electric X353-5B propulsion systems shall be used (see Figure 38), Propulsion systems shall be in accordance with G. E. Specification 112, dated 15 January 1962. A General Electric X376 Pitch Fan shall be installed in the forward fuselage section and shall be in accordance with G. E. specification number 113, dated 1 March 1962.

3.12.1.1 Each gas producer (J-85) shall power one-half of each fan turbine. Engine cross-coupling ducts shall be provided to accommodate single engine power loss. Single engine power loss shall not produce unsymmetric loading between the fans. A tailpipe shroud and ejector system shall be employed to remove cooling air from the engine compartment during conventional flight. Engine-driven fans shall be provided to augment cooling during VTOL flight. See Figure 39. Nose fan bleed duct shrouds shall be cooled by engine driven fans which supply air along the ducts, and discharge into the pitch fan inlet duct. Wing fans shall be cooled by forced flow from engine driven fans past the scrolls, and discharged into the fan inlets. A thrust spoiler device shall be employed to allow low forward thrust component at high gas producer output, to aid in conversion from

conventional to fan powered flight. Cockpit throttles shall be provided to permit individual or collective control of the gas generators. A conventional throttle quadrant shall be provided at the left of the pilot for individual control of gas generator output. A twist grip on the collective lift control shall afford joint regulation of gas producer power.

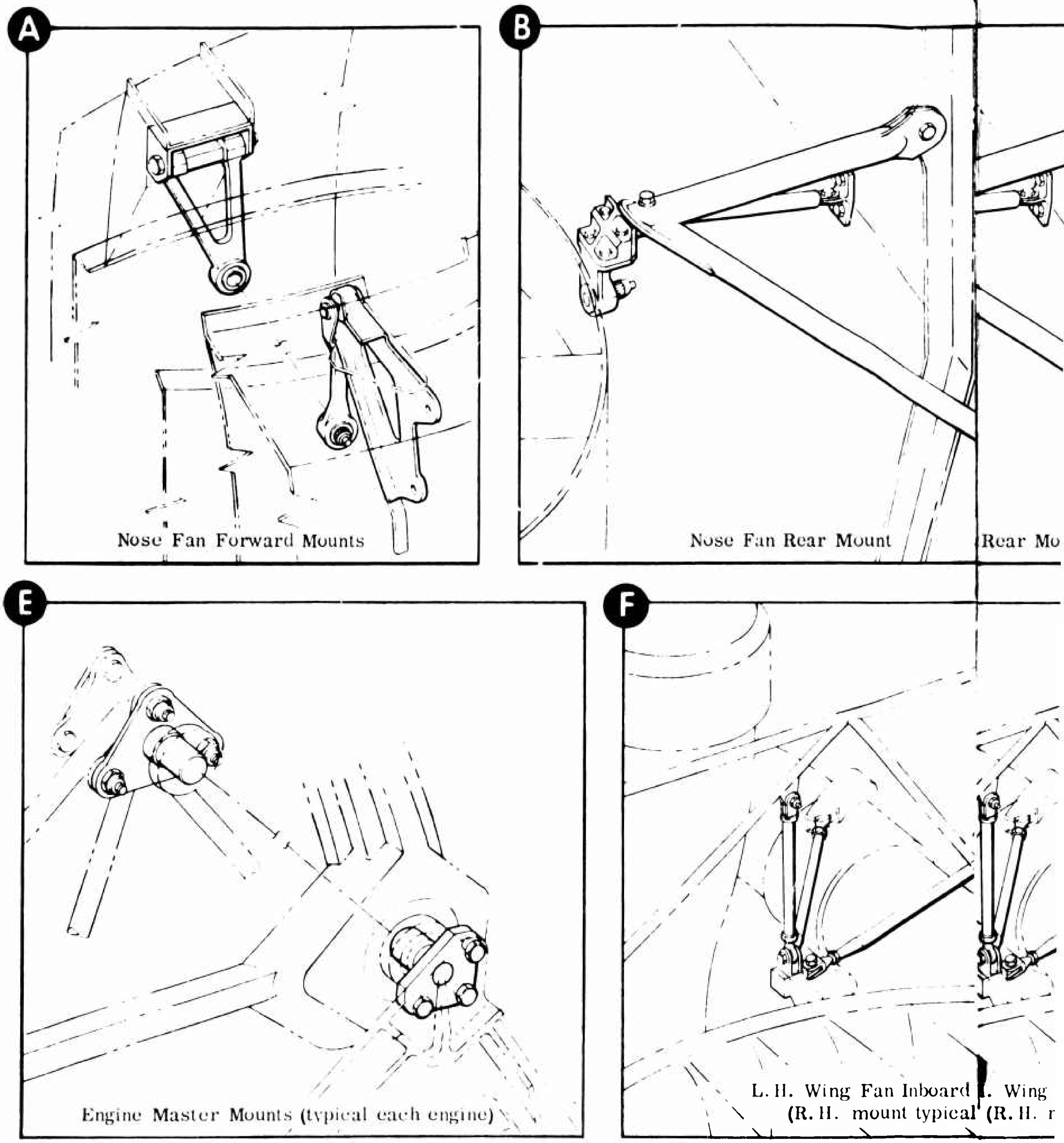
3.12.1.2 An air impingement starter system shall be provided. Starter ducts shall be routed from each engine, and shall terminate at an external connector installation located in the lower portion of the center fuselage bay. System installation shall provide for individual engine starting. Check valves shall be provided in each engine starter installation.

3.12.1.3 The aircraft fuel system (see Figures 40 and 41) shall consist of a main fuel system and an extended range fuel system. The main system shall consist of a forward and aft fuel tank having 2520 pounds total capacity. The extended range system shall consist of a forward belly tank, and aft belly tank, and a dorsal tank located in the aft fuselage section above the engine tailpipes. Total capacity using the extended range system shall be 4650 pounds. Extended range tank weight shall not be included as part of aircraft empty weight, but shall be considered as payload. All fuel tanks shall be provided with fuel vent lines and overboard vent fittings with screens. All tanks shall be provided with fuel sumps containing water drain lines and valves. The main system tanks shall contain cross-feed lines and valves. Extended range system tanks shall be provided with fuel transfer lines and shutoff valves. All fuel tanks, with exception of dorsal tank, shall contain fuel boost pumps with sufficient capacity to maintain fuel system pressures. The dorsal tank normally shall gravity feed and shall not require a boost pump; however, provisions shall be included for adding a boost pump and sump to permit alternate tank usage. Fuel strainers shall be provided in the main system fuel lines between the engines and the fuel tanks. Main system lines shall contain low-pressure warning switches.

3.12.2 Installed Power Plant Performance. -

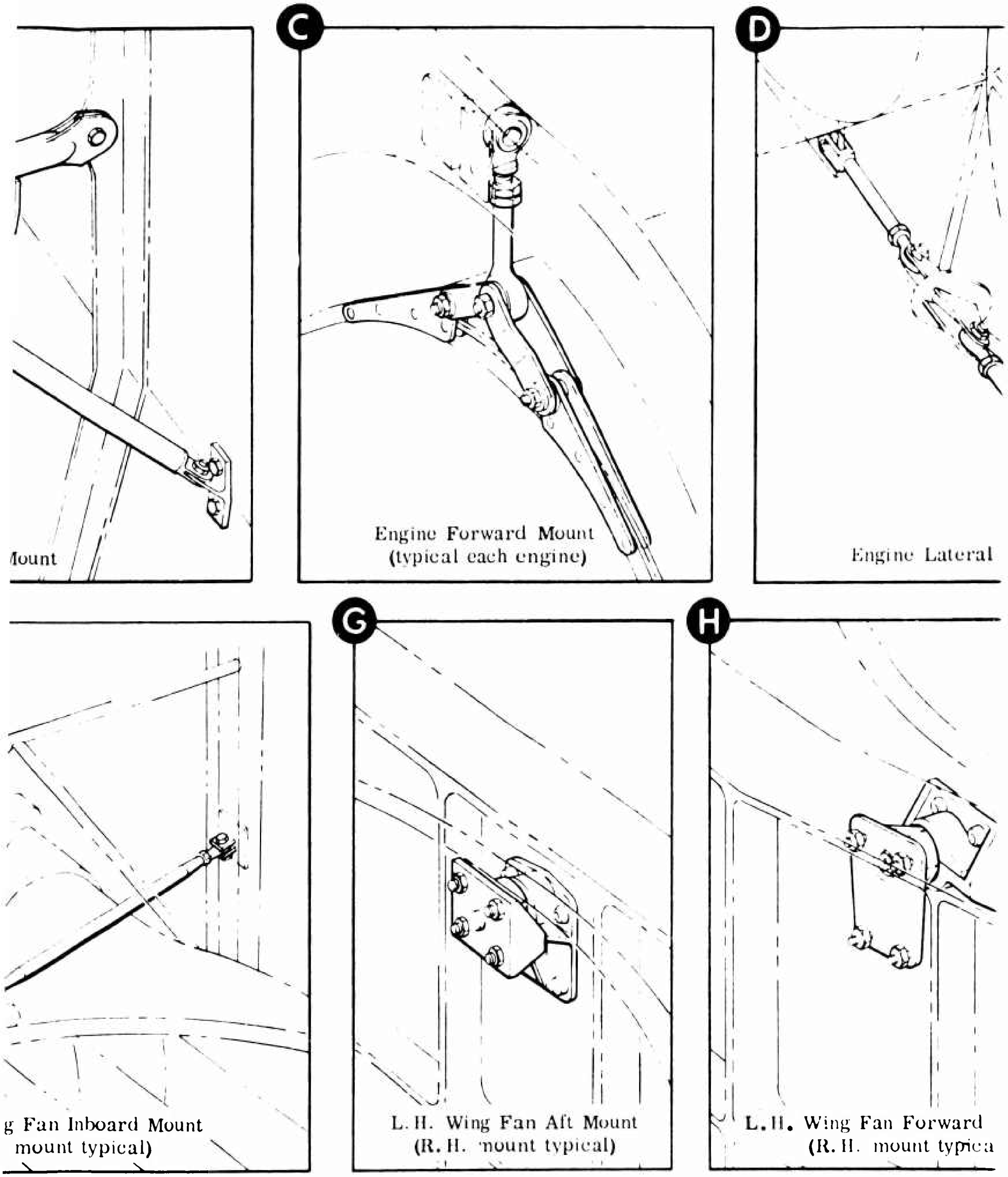
3.12.2.1 Installed conventional mode power plant performance shall be calculated using a General Electric supplied engine performance computer deck describing the X353-5B propulsion system. Installation losses involved in the calculations shall include: engine inlet pressure recovery, engine inlet drag, gas producer power extraction, gas producer turbine discharge bleed, conventional flight exhaust duct loss, and tailpipe cooling ejector loss. Hovering performance shall be calculated using a computer deck and/or the X353-5B propulsion system specification.

3.12.2.2 The engine air inlets shall be sized to minimize losses during lift fan operation, and to provide satisfactory performance at high flight speeds. A boundary layer bleed duct approximately 16 square inches shall be located under the inlets, and furnish cooling air for engine installations. Estimated inlet pressure recovery is


A
Nose Fan Forward Mounts
B
Nose Fan Rear Mount
Rear Mo
E
Engine Master Mounts (typical each engine)
F
L. H. Wing Fan Inboard
(R. H. mount typical
L. Wing
(R. H. r

8-218-43

A



Mount

Engine Forward Mount
(typical each engine)

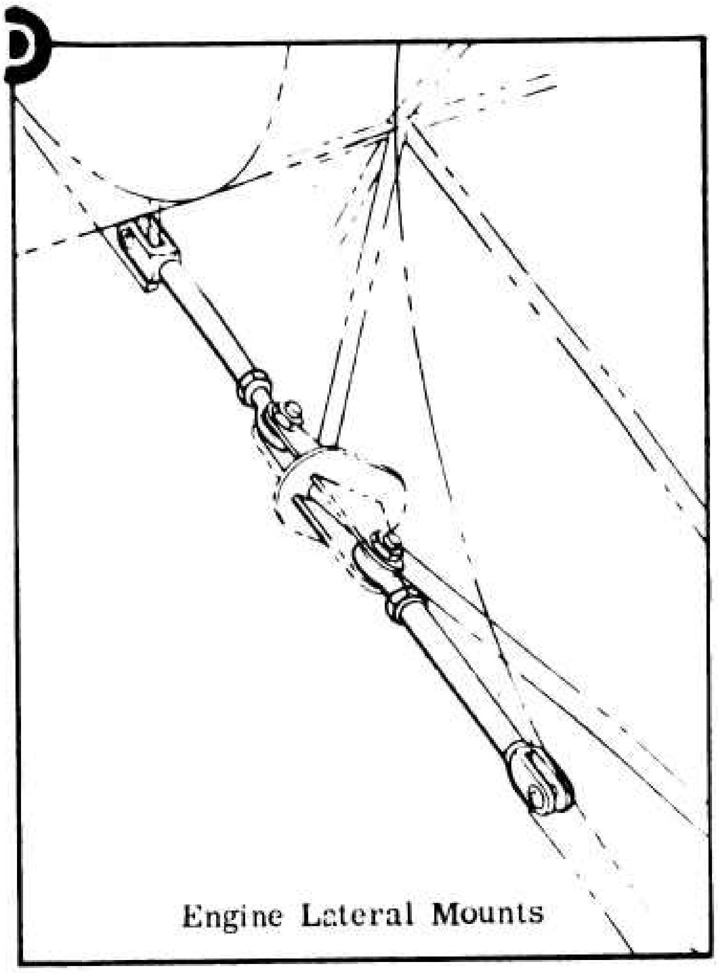
Engine Lateral

g Fan Inboard Mount
mount typical)

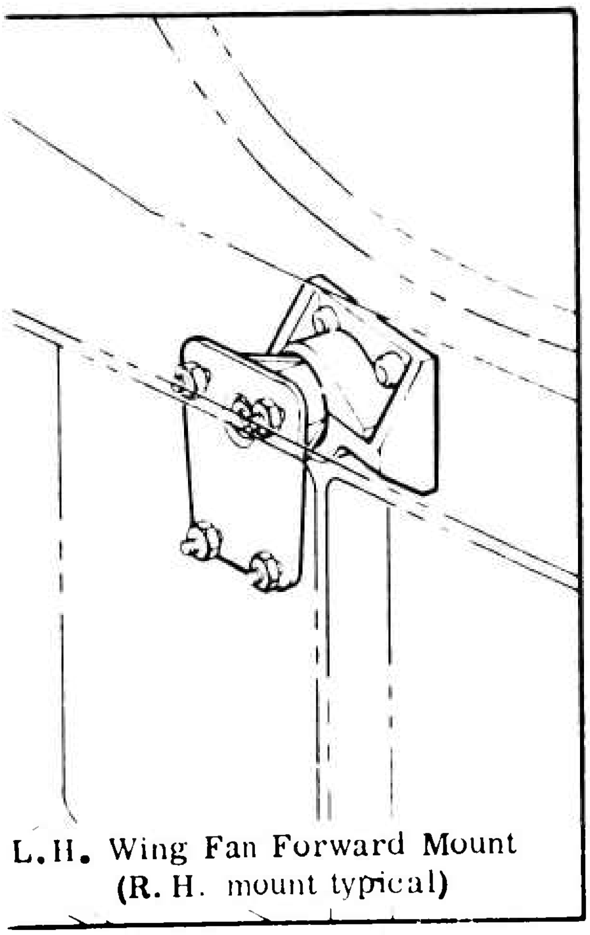
L.H. Wing Fan Aft Mount
(R.H. mount typical)

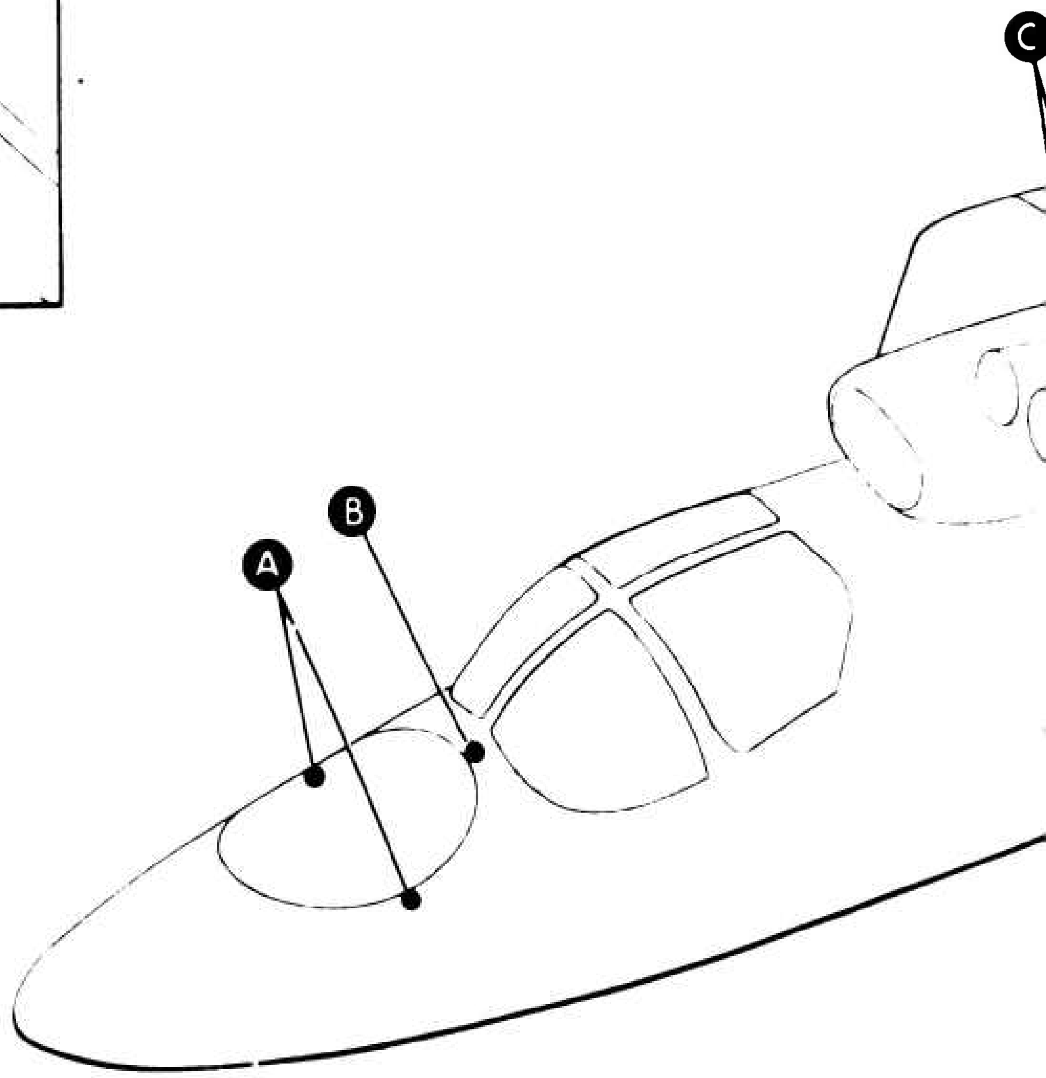
L.H. Wing Fan Forward
(R.H. mount typica

B



Engine Lateral Mounts


L.H. Wing Fan Forward Mount
(R. H. mount typical)



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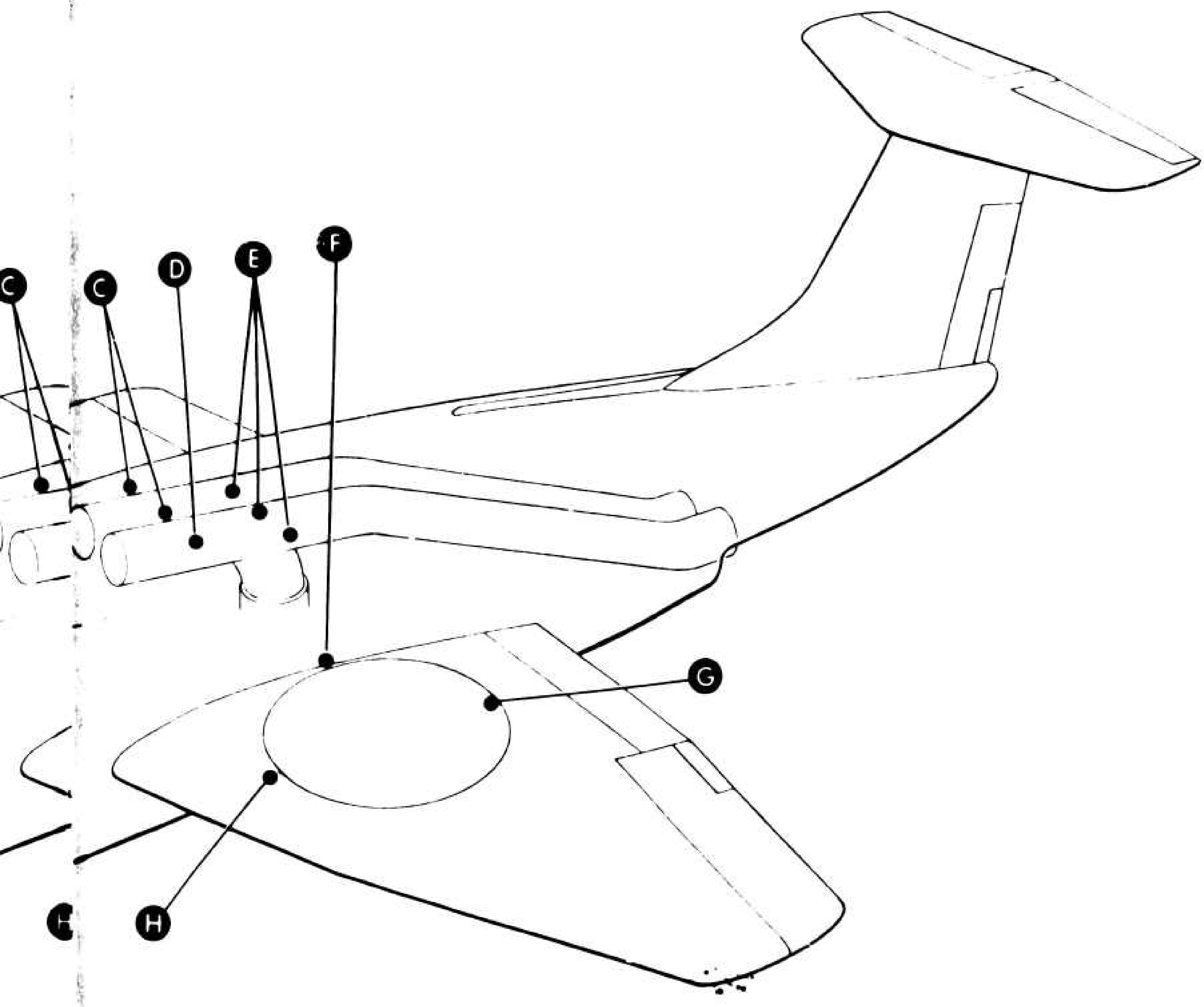
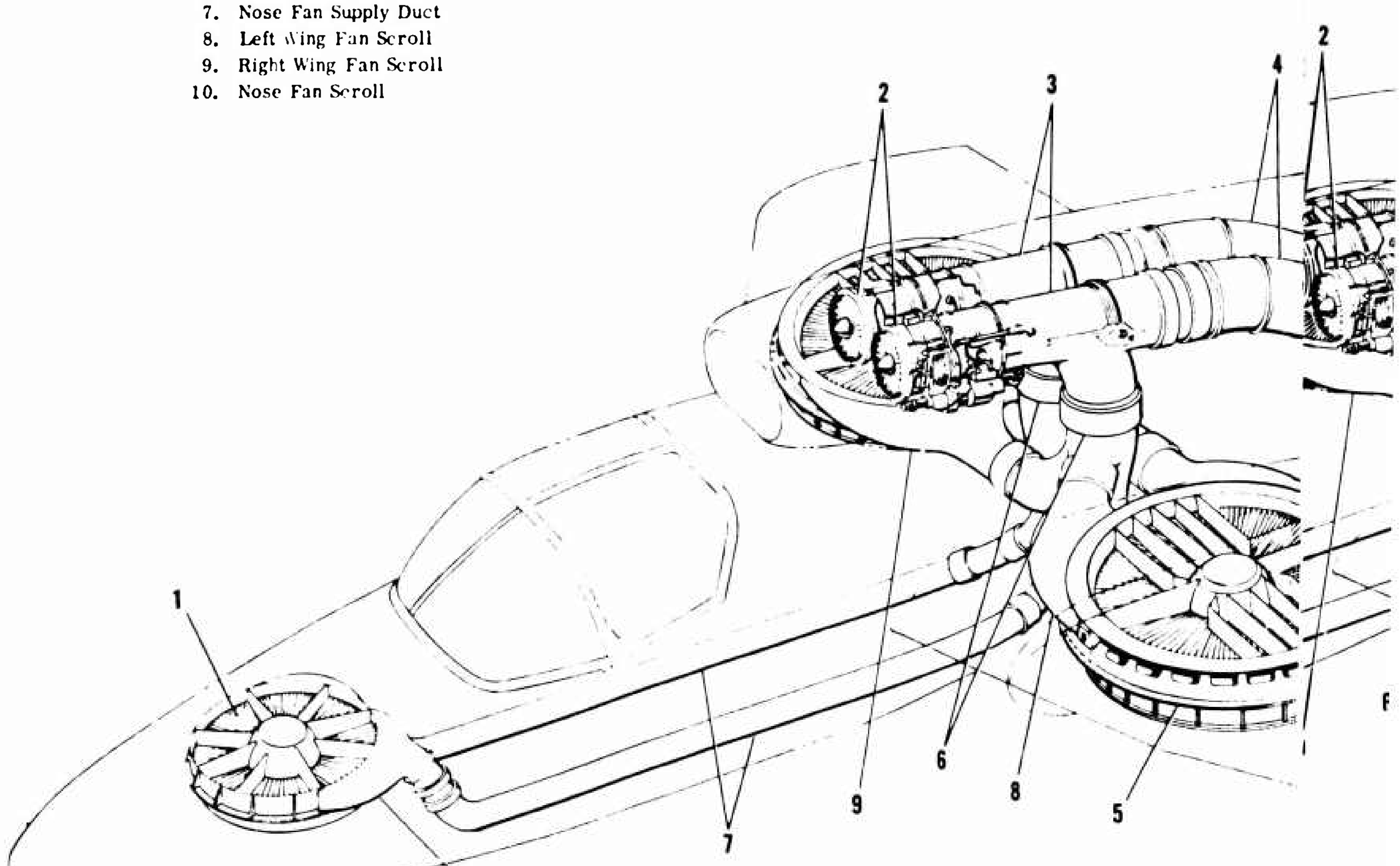


Figure 37 Propulsion System Mounting

1. Nose Fan
2. Gas Generator
3. Diverter Valve
4. Engine Tail Pipe
5. Wing Fan
6. Crossover Ducts
7. Nose Fan Supply Duct
8. Left Wing Fan Scroll
9. Right Wing Fan Scroll
10. Nose Fan Scroll



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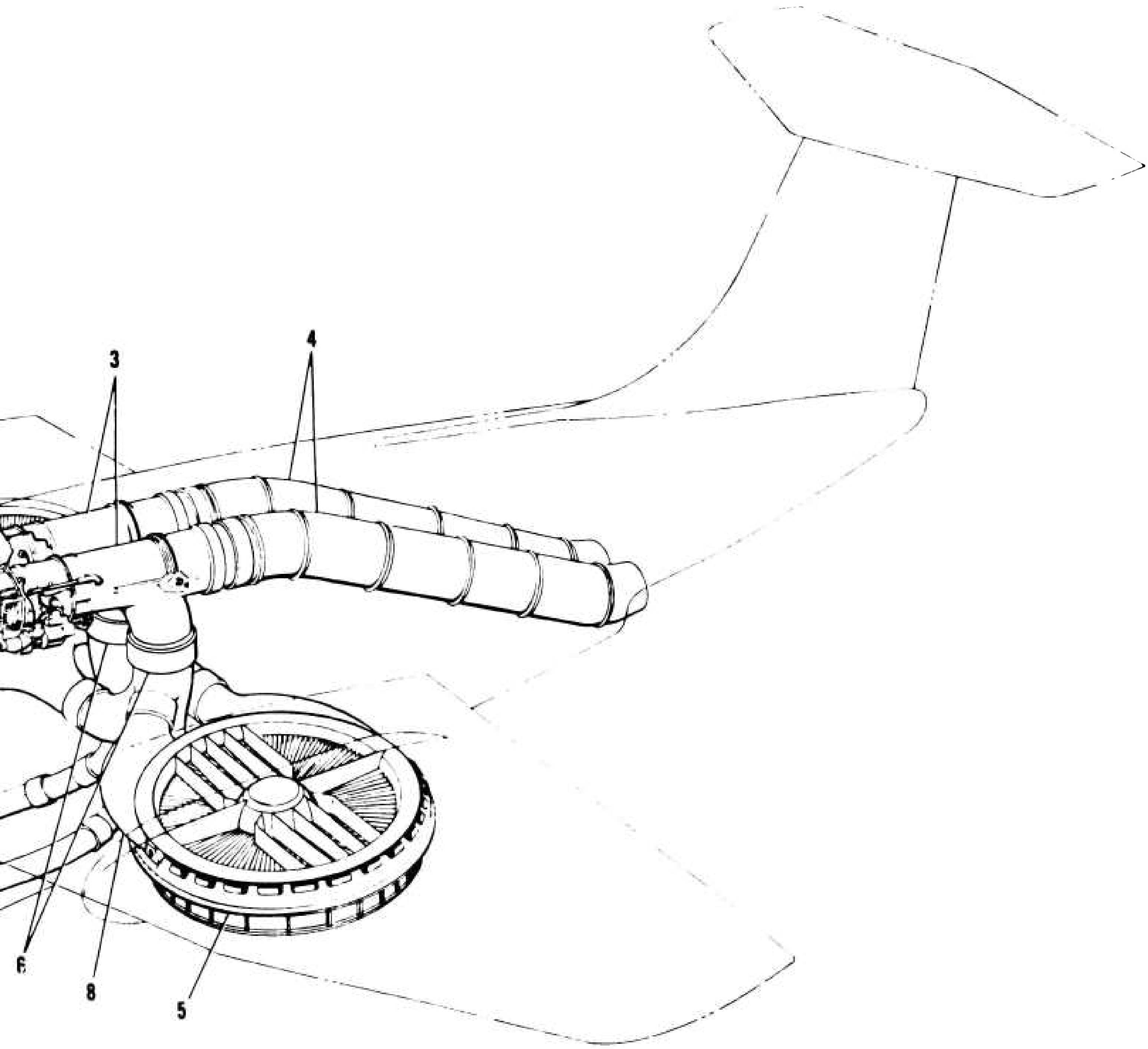
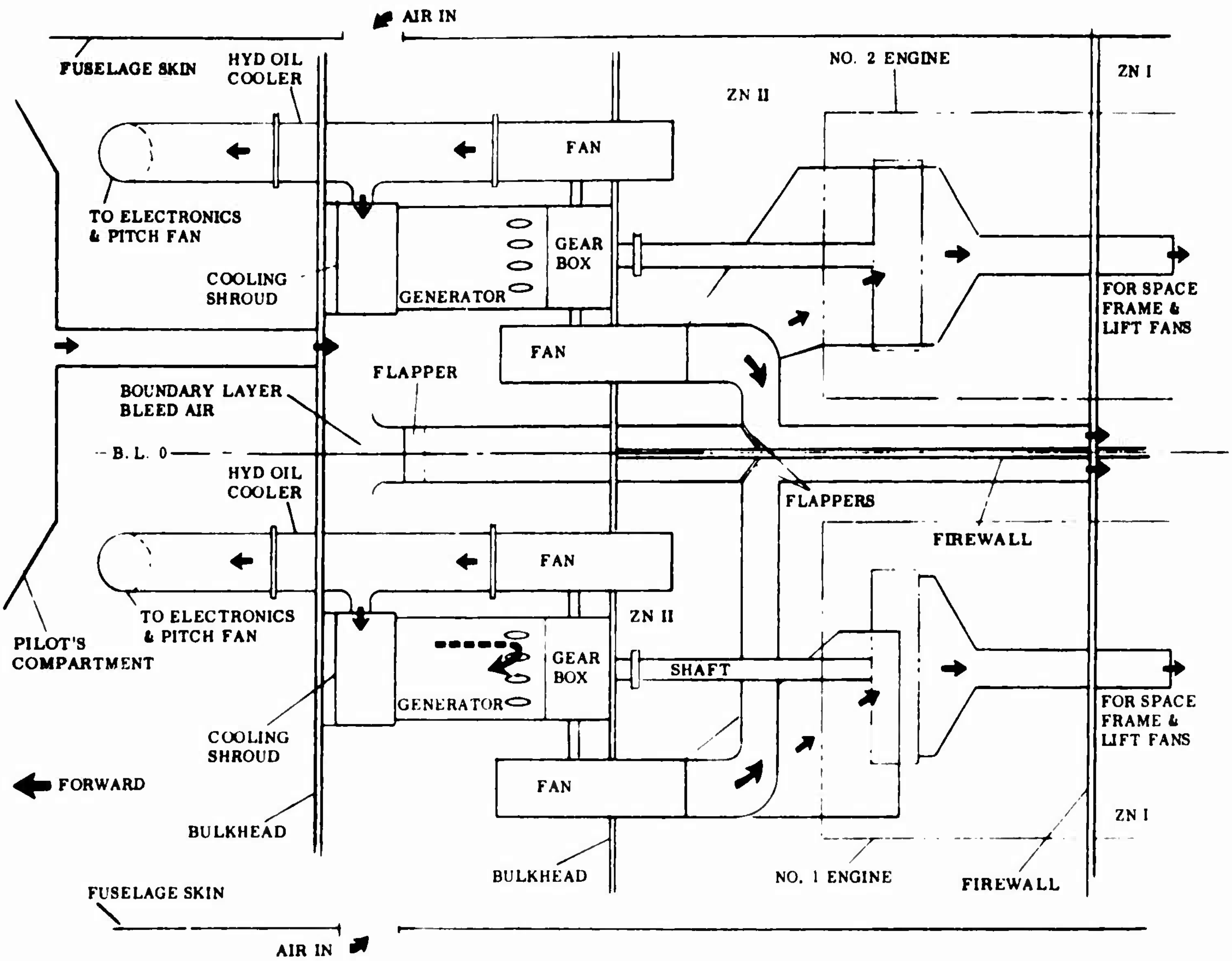


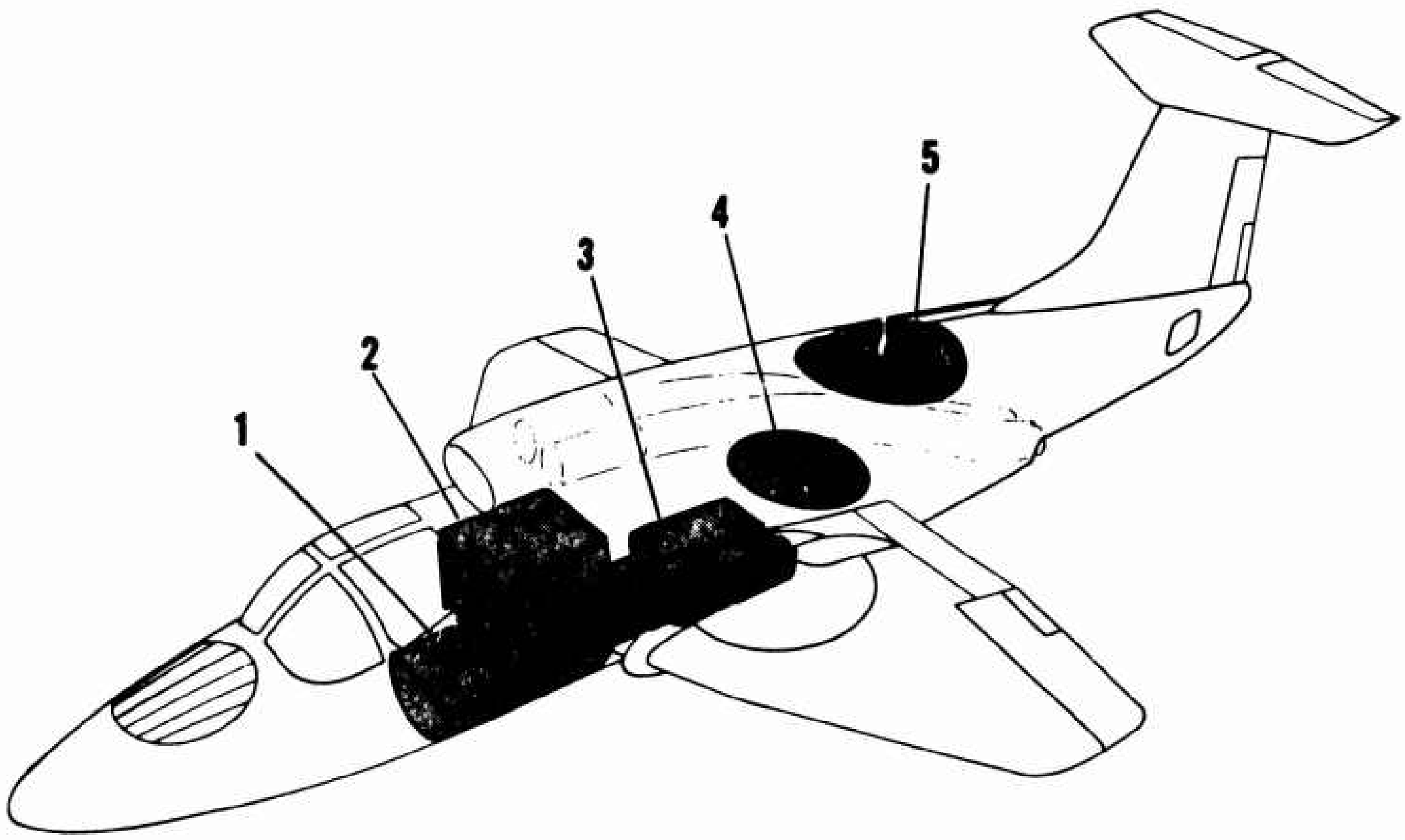
Figure 38 Propulsion System Components

B



R-218-44

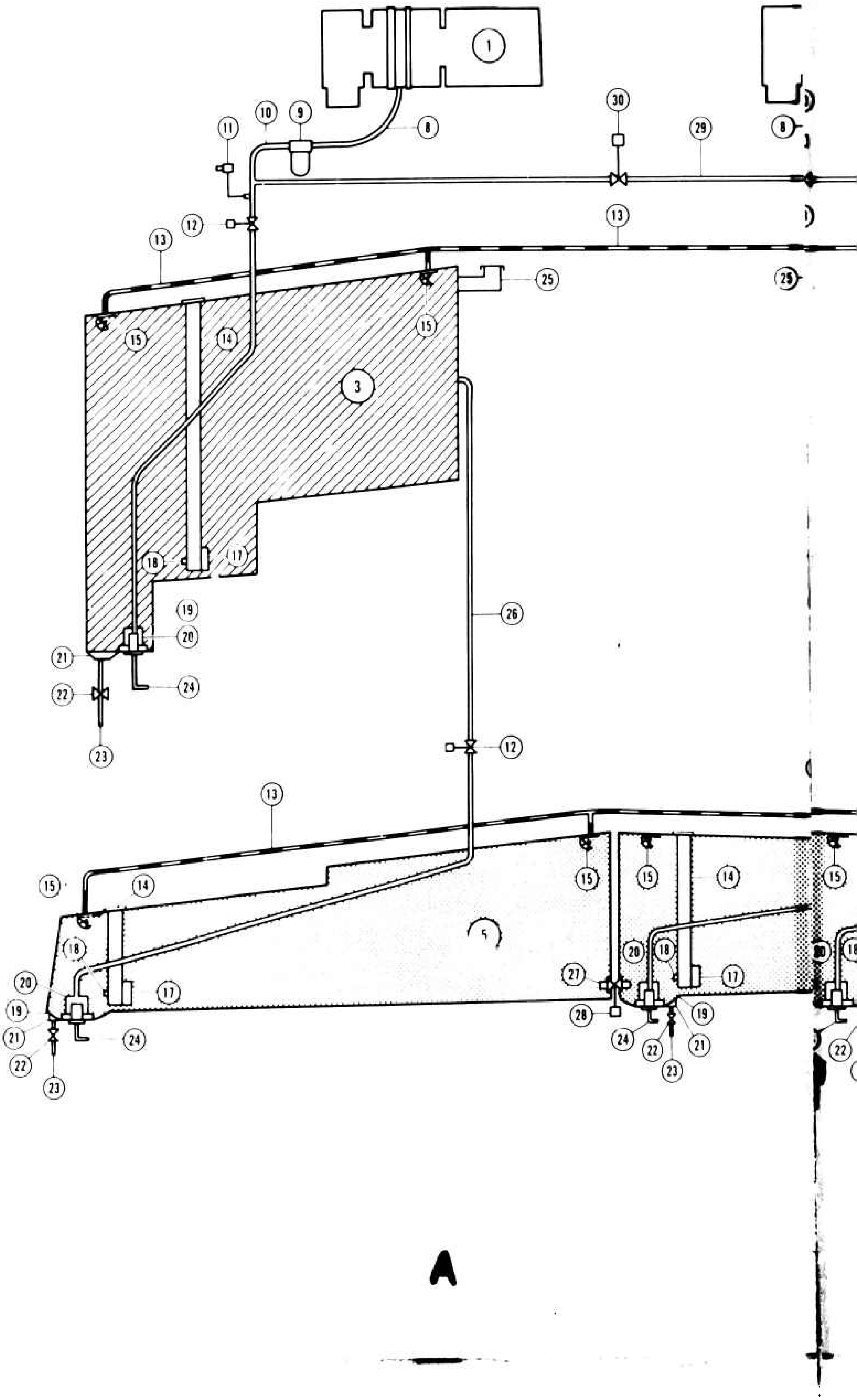
Figure 39 Propulsion Subsytem Cooling Diagram



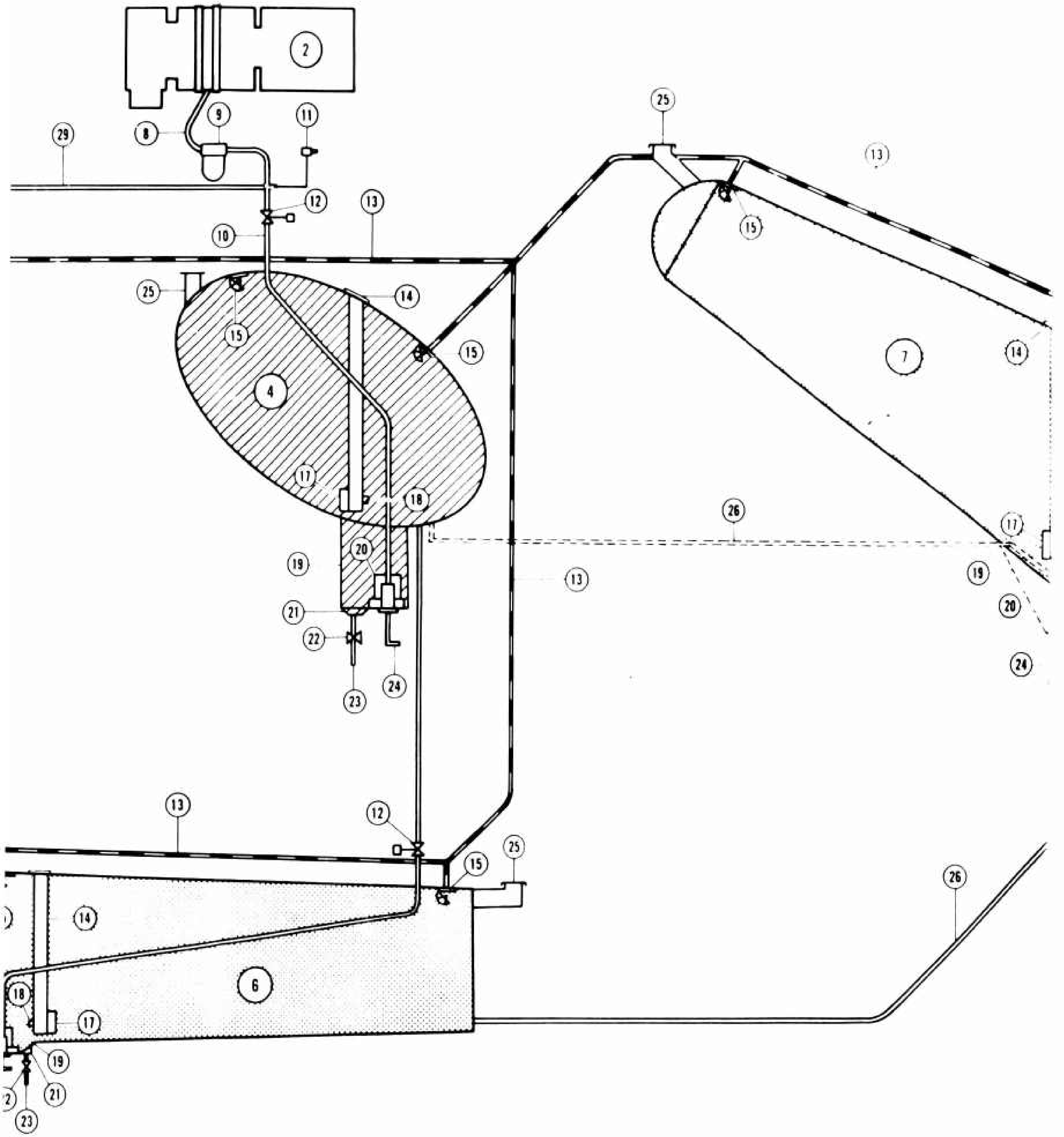
1. Extended Range Forward Belly Tank - 666# fuel
2. Forward Main Fuel Tank - 1710# fuel
3. Extended Range Aft Belly Tank - 850# fuel
4. Aft Main Fuel Tank - 810# fuel
5. Extended Range Dorsal Tank - 615# fuel

R-210-46

Figure 40 Fuel System Tank Location Diagram



A


2
25
13
29
8
9
11
12
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25
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18
26
17
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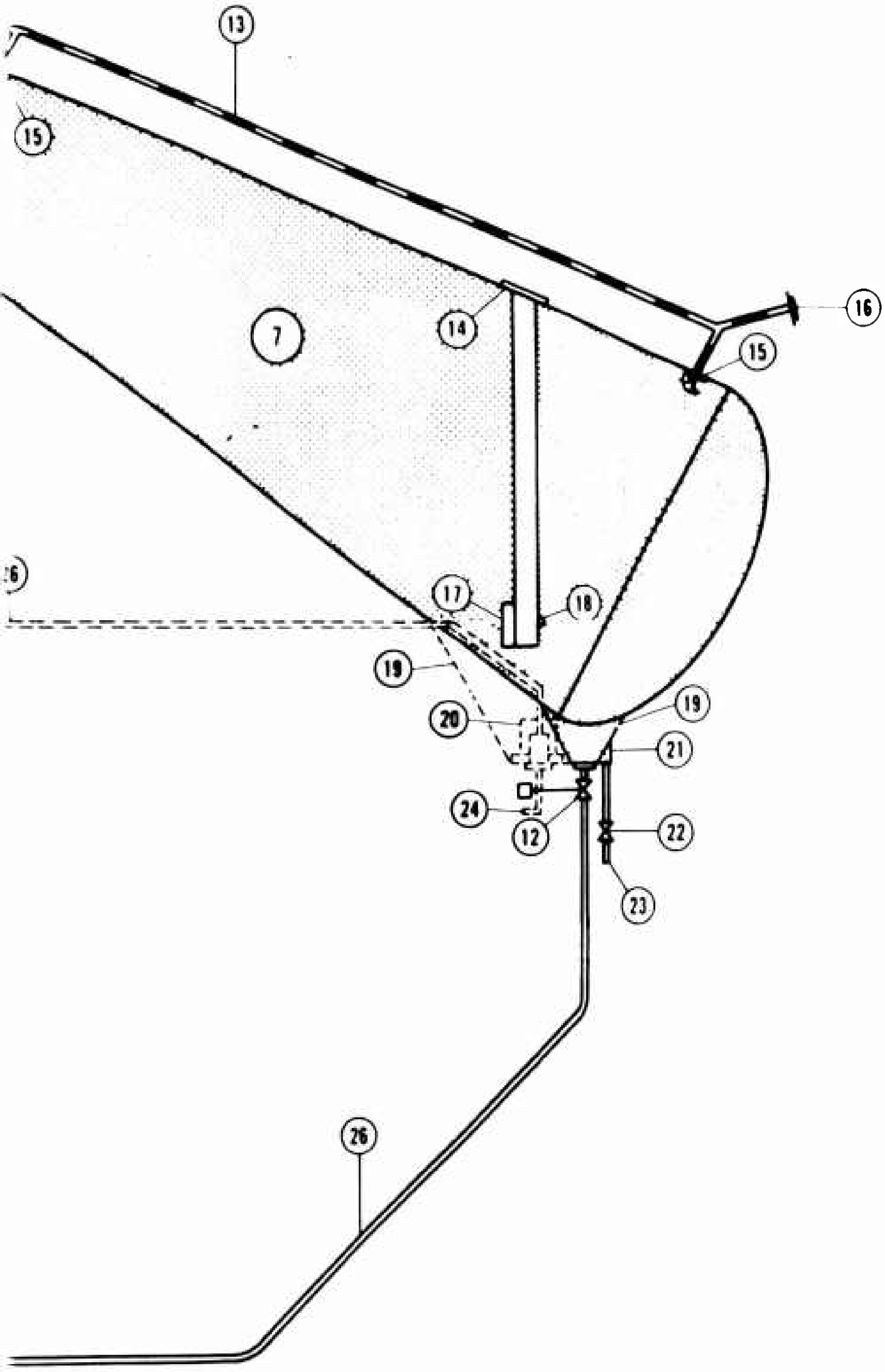
23

B



1 LEFT HAND ENGINE
2 RIGHT HAND ENGINE
3 FORWARD MAIN TANK
4 AFT MAIN TANK
5 FORWARD BELLY TANK
6 AFT BELLY TANK
7 DORSAL TANK
8 FLEX HOSE
9 FUEL STRAINER
10 MAIN FUEL SUPPLY LINE
11 LOW PRESSURE WARNING SWITCH
12 FUEL SHUT OFF VALVE
13 VENT LINE
14 FUEL QUANTITY PROBE
15 FLOAT OPERATED VENT VALVE
16 OVERBOARD VENT FITTING WITH SCREEN
17 FUEL COMPENSATOR
18 LOW LEVEL WARNING SWITCH
19 SUMP
20 BOOST PUMP
21 WATER DRAIN
22 DRAIN VALVE
23 DRAIN LINE
24 PUMP SEAL DRAIN
25 TANK FILLER WITH STRAINER
26 FUEL TRANSFER LINE (1.0 DIA.)
27 FUEL TRANSFER LINE (2.0 DIA.)
28 FUEL SHUT OFF VALVE (2.0 DIA.)
29 CROSS FEED LINE
30 CROSS FEED VALVE

MAIN FUEL TANKS

EXTENDED RANGE FUEL TANKS

FUEL LINES

VENT LINES

ALTERNATE TANK ARRANGEMENT
(TANKS 5 AND 6 REMOVED)

Figure 41 Aircraft Fuel System Schematic Diagram

C

presented in Figure 42. Estimated external drag increment coefficient is shown in Figure 43.

3.12.2.3 Gas producer power extraction losses shall be based on steady-state daylight operation. In the conventional flight mode, 13 horsepower shall be extracted from each engine to accommodate hydraulic drive, cooling fan, and electrical system requirements. In fan flight mode, 25 horsepower shall be extracted from each engine.

3.12.2.4 Engine tailpipes shall be approximately 120 inches long, with 2 bends of 20 degrees each located near each end of the tailpipes. Conventional flight exhaust duct loss shall be calculated using methods supplied by General Electric. Estimated loss is presented in Figure 44. Preliminary tailpipe ejector performance shall be based on a boundary layer bleed inlet area of approximately 16 square inches, and a conical cooling air ejector. Tailpipe ejector performance is presented in Figures 45 and 46.

3.12.2.5 Nose-fan lift data shall be based on a lift capability of 1300 pounds at 2500 feet, ANA 421 hot day. This capability results in a 10.6 percent turbine discharge bleed factor which is included in all installed lift performance data used in this specification.

3.13 Secondary Power and Distribution Subsystems. -

3.13.1 Electrical Power Generation and Distribution Subsystem. - See Figures 47 and 48. Electrical power shall be supplied by two engine-driven 28 VDC generators. Emergency power shall be supplied by battery. Electrical power conversion shall be accomplished by two 115 V AC, 400 cycle, static inverters. Each inverter shall be capable of supplying normal current loads. In event of power loss of one inverter, electrical loads shall be automatically transferred to the other inverter. An external power receptacle shall be provided for ground checkout.

3.13.2 Hydraulic Power Generation and Distribution Subsystem. - Two independent hydraulic systems shall be provided, (see Figure 49). Each system shall operate continuously, and be capable of supplying full load requirements in event of pressure loss of one system. Both systems shall use engine-driven pumps. Hydraulic power shall be provided to control actuators through tandem cylinders positioned by servo control and solenoid valves. Pressure transmitters in each system shall supply signals to a dual reading hydraulic pressure gage located in the cockpit. Provisions shall be included for cockpit warning in event of system pressure loss. External ground-test connections shall be provided to facilitate filling and system checkout.

3.13.2.1 The following control elements (Figure 50) shall be hydraulically actuated: wing fan exit louvers, wing fan inlet doors, engine diverter valves, pitch fan controls, main landing gear actuation, nose landing gear actuation, brakes, horizontal stabilizer, thrust spoilers, ailerons.

ESTIMATED INLET PRESSURE RECOVERY

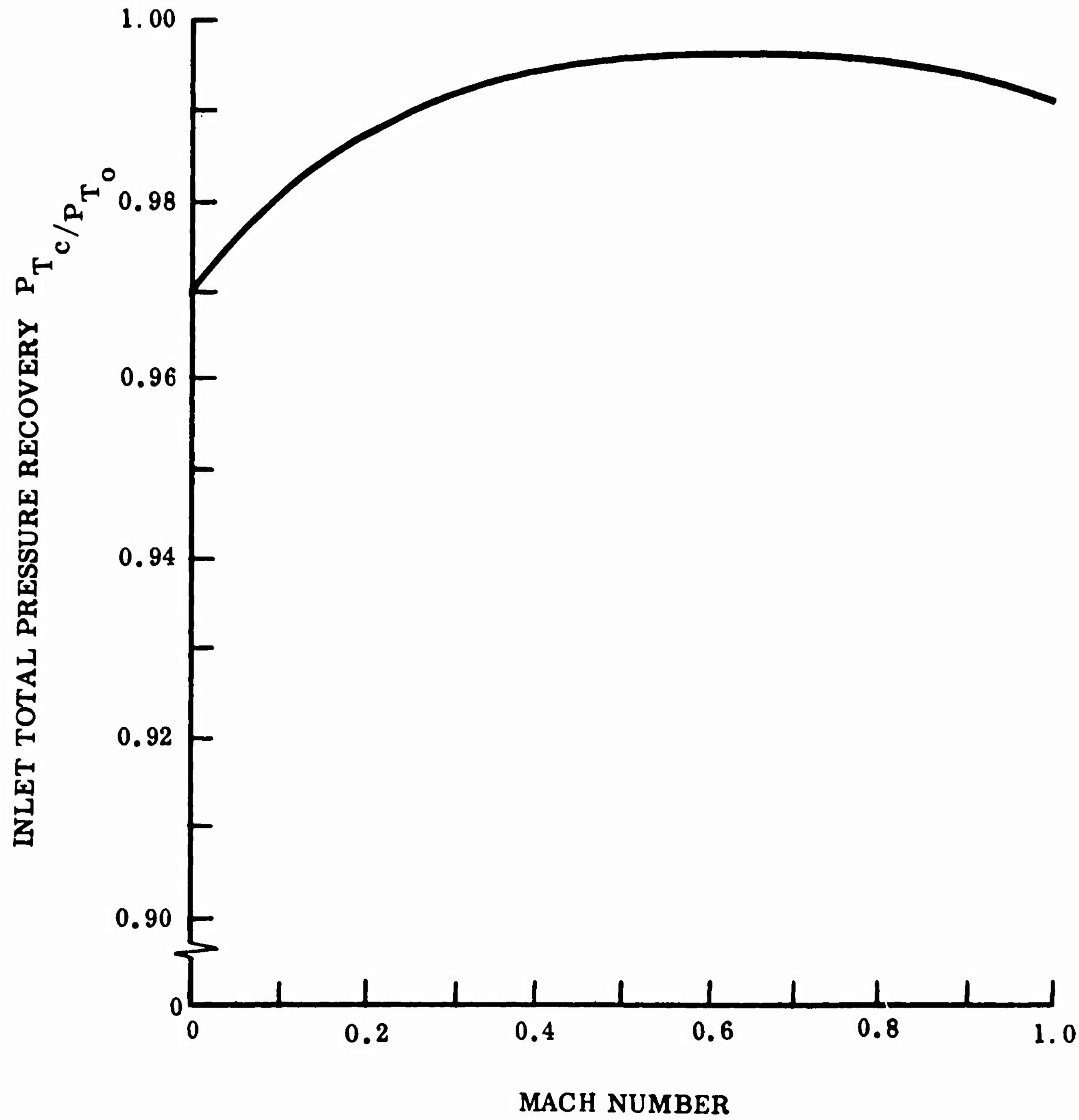


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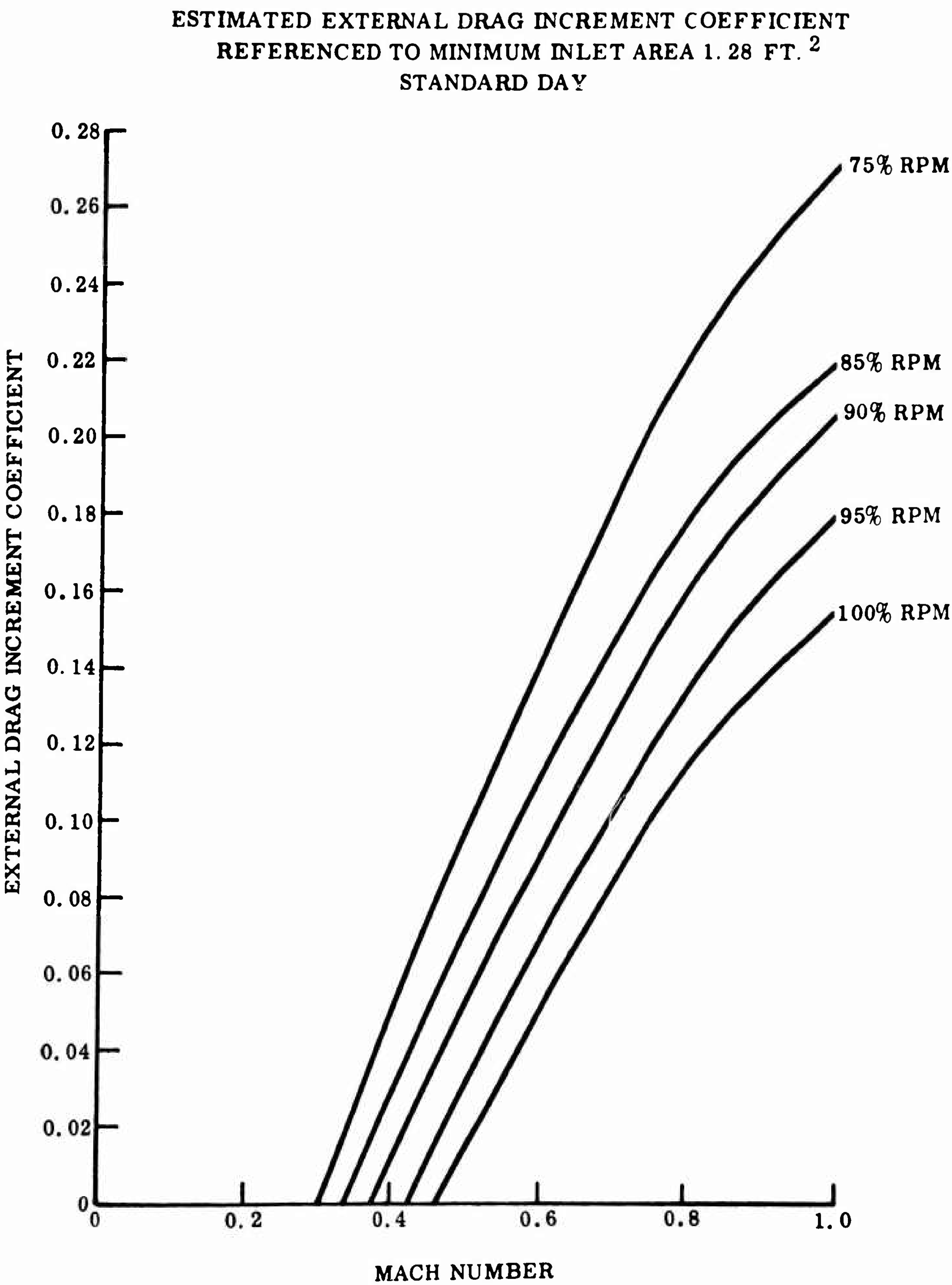
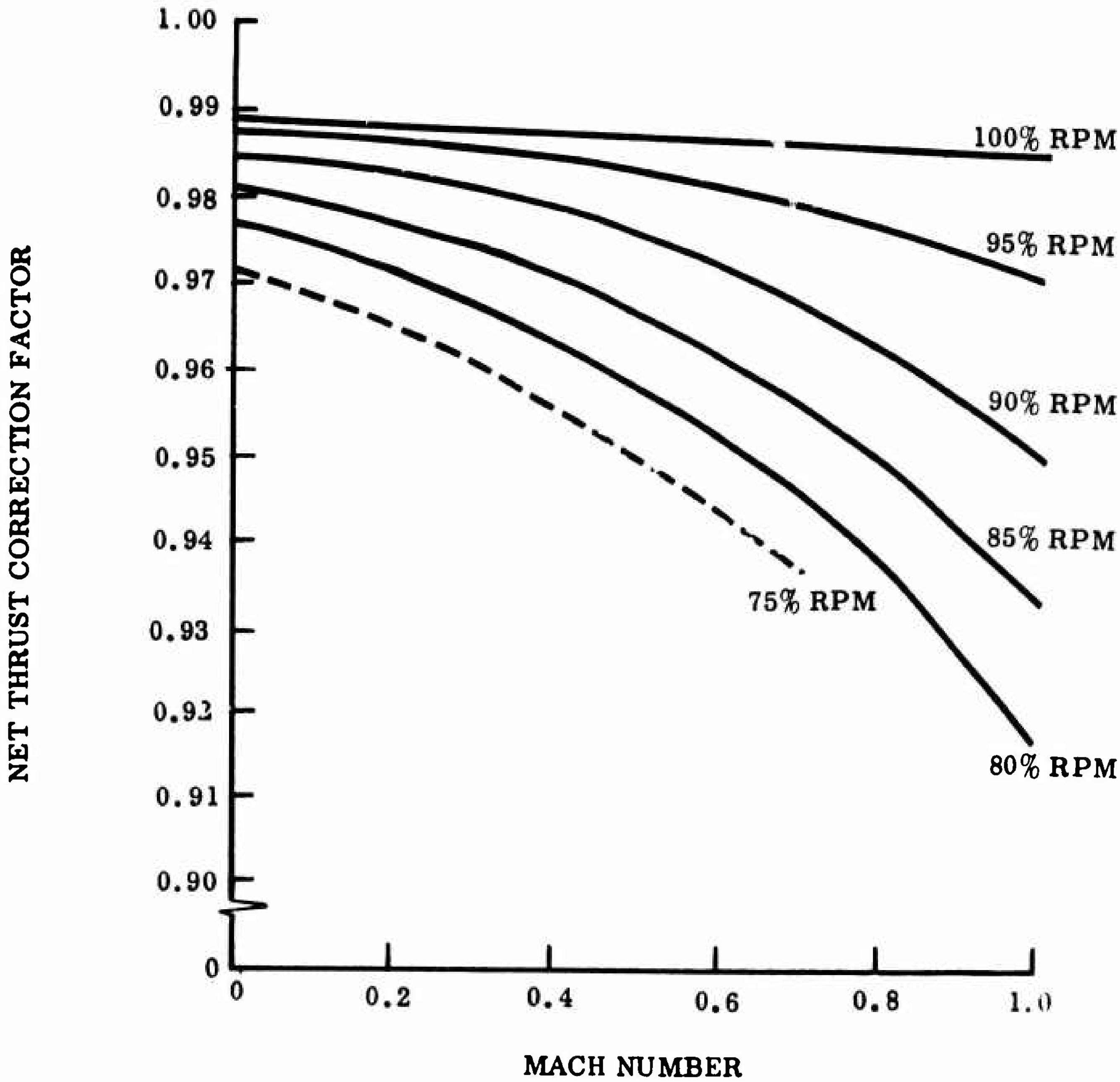
Figure 42 Estimated Inlet Pressure Recovery



R-210-30 Figure 43 Estimated External Drag Increment Coefficient

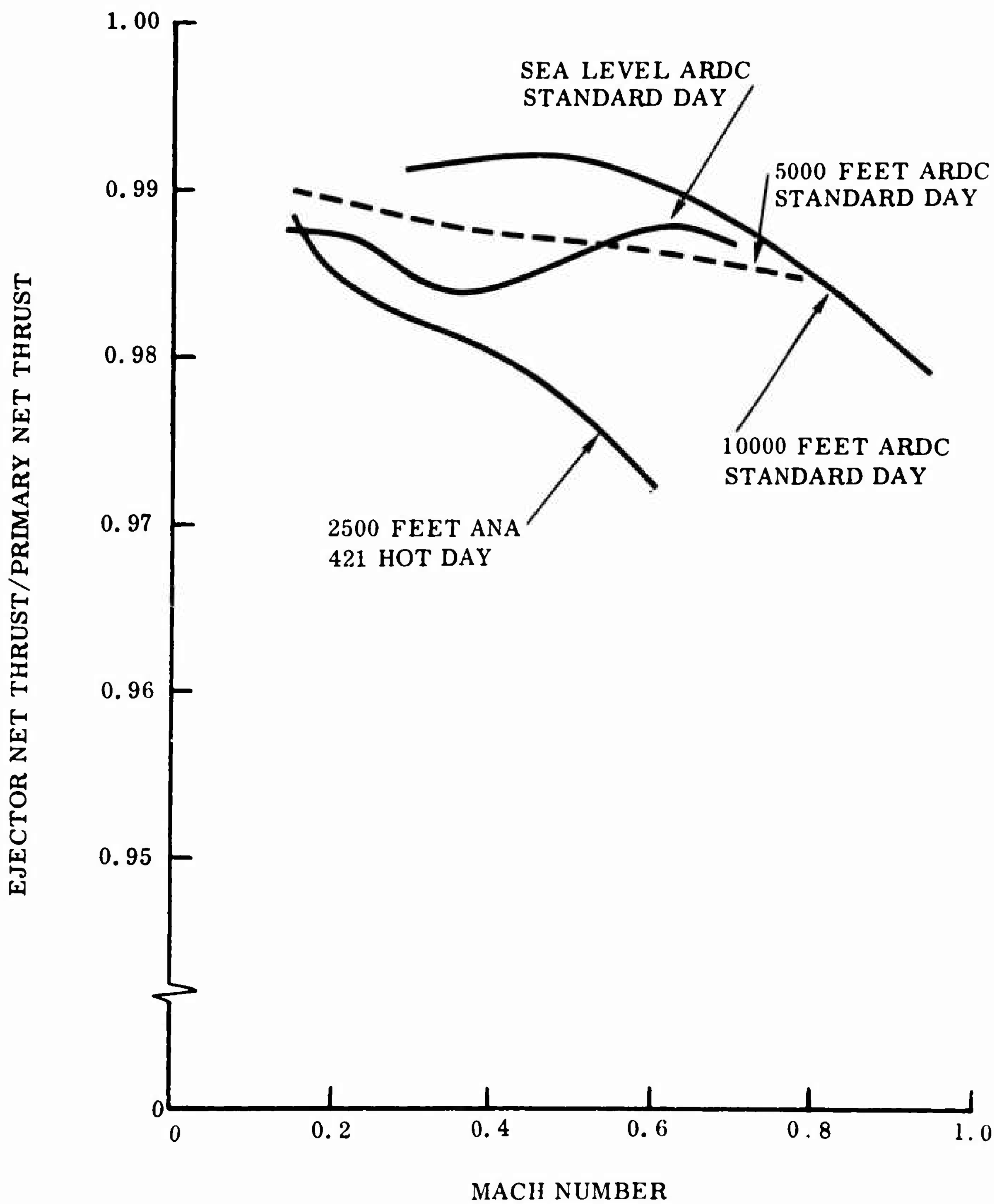
ESTIMATED EXHAUST DUCT LOSS
CONVENTIONAL FLIGHT MODE



8-210-39

Figure 44 Estimated Exhaust Duct Loss

EJECTOR NET THRUST/PRIMARY NET THRUST VERSUS MACH NUMBER
MILITARY POWER



R-218-40 Figure 45 Ejector Net Thrust/Primary Net Thrust Versus Mach Number

COOLING WEIGHT FLOW/GAS GENERATOR WEIGHT FLOW VERSUS MACH NUMBER
MILITARY POWER

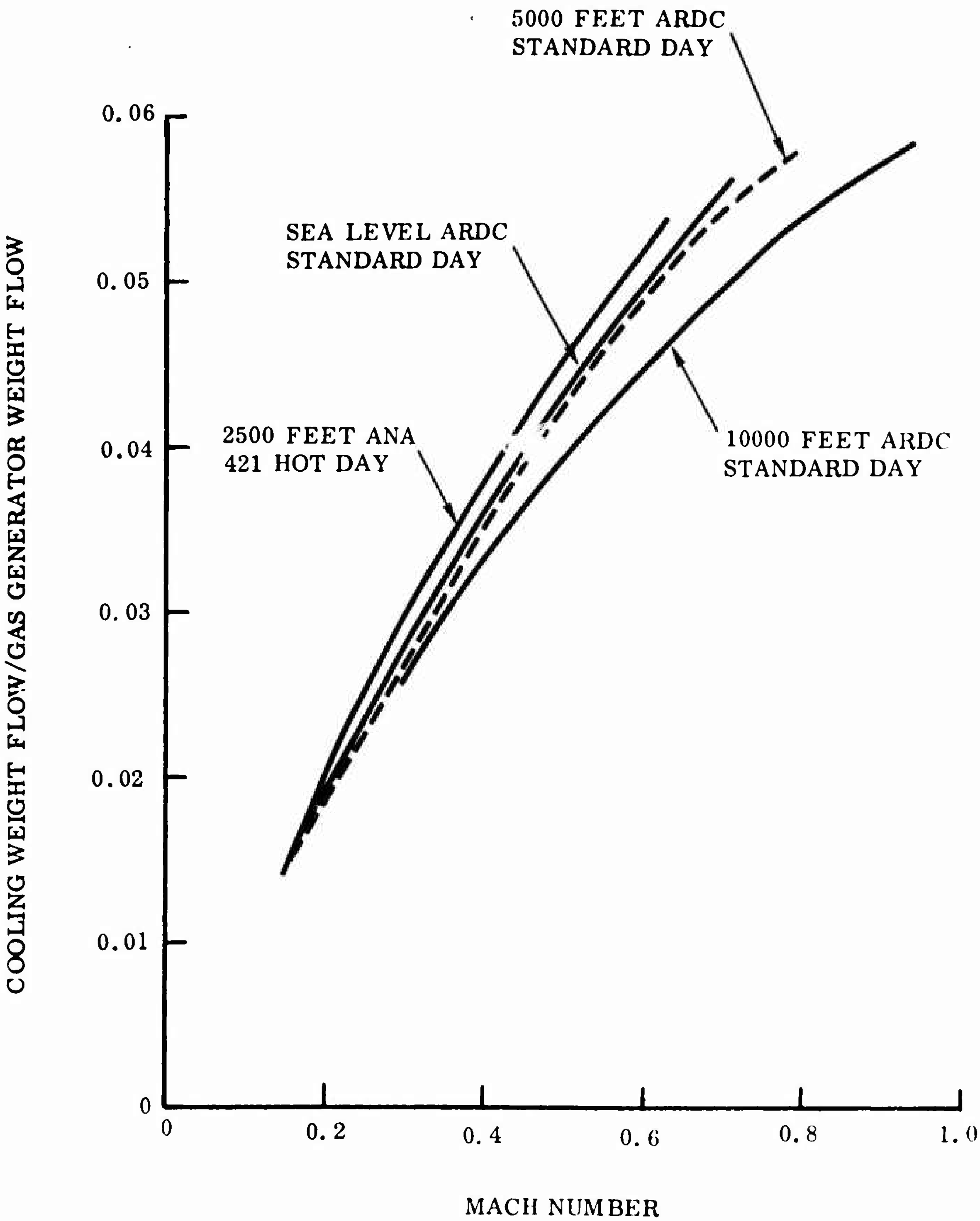


Figure 46 Cooling Weight Flow/Gas Generator Weight Flow Versus Mach Number

P-218-41

3.13.3 Pneumatic Power Generation and Distribution Subsystem. - A gaseous nitrogen (GN_2) system shall be provided (see Figure 51). The system shall provide for emergency landing gear actuation in event of hydraulic system pressure loss. Gaseous nitrogen shall be stored in main landing gear cylinders.

3.14 Utilities and Equipment Subsystems. -

3.14.1 Air Conditioning. - Cockpit cooling and ventilation shall be supplied in the form of fresh ram air. An exhaust fan shall be provided to remove stale air from the cockpit. Provisions shall not be made for air conditioning.

3.14.2 Anti-Icing. - Anti-icing shall not be provided.

3.14.3 De-Fogging. - Circulating fresh air shall be provided for windshield de-fogging.

3.14.4 Moisture Control. - Moisture control shall not be provided.

3.14.5 Pressurization. - Cockpit pressurization shall not be provided.

3.14.6 Fire Radiation Hazard Detection. - Fire detection and indicating systems shall be installed in the engine compartment, and hot gas duct areas, in accordance with specification MIL-D-7006A(ASG).

3.14.7 Fire Prevention. - Fire prevention features shall be provided in the form of engine firewalls, isolation areas, and heat shields.

3.14.8 Fire Protection. - Fire extinguishing systems shall be provided in the engine compartment.

3.15 Mission and Air Traffic Control Subsystems. -

3.15.1 Communications Subsystem. - A UHF communications system shall be provided.

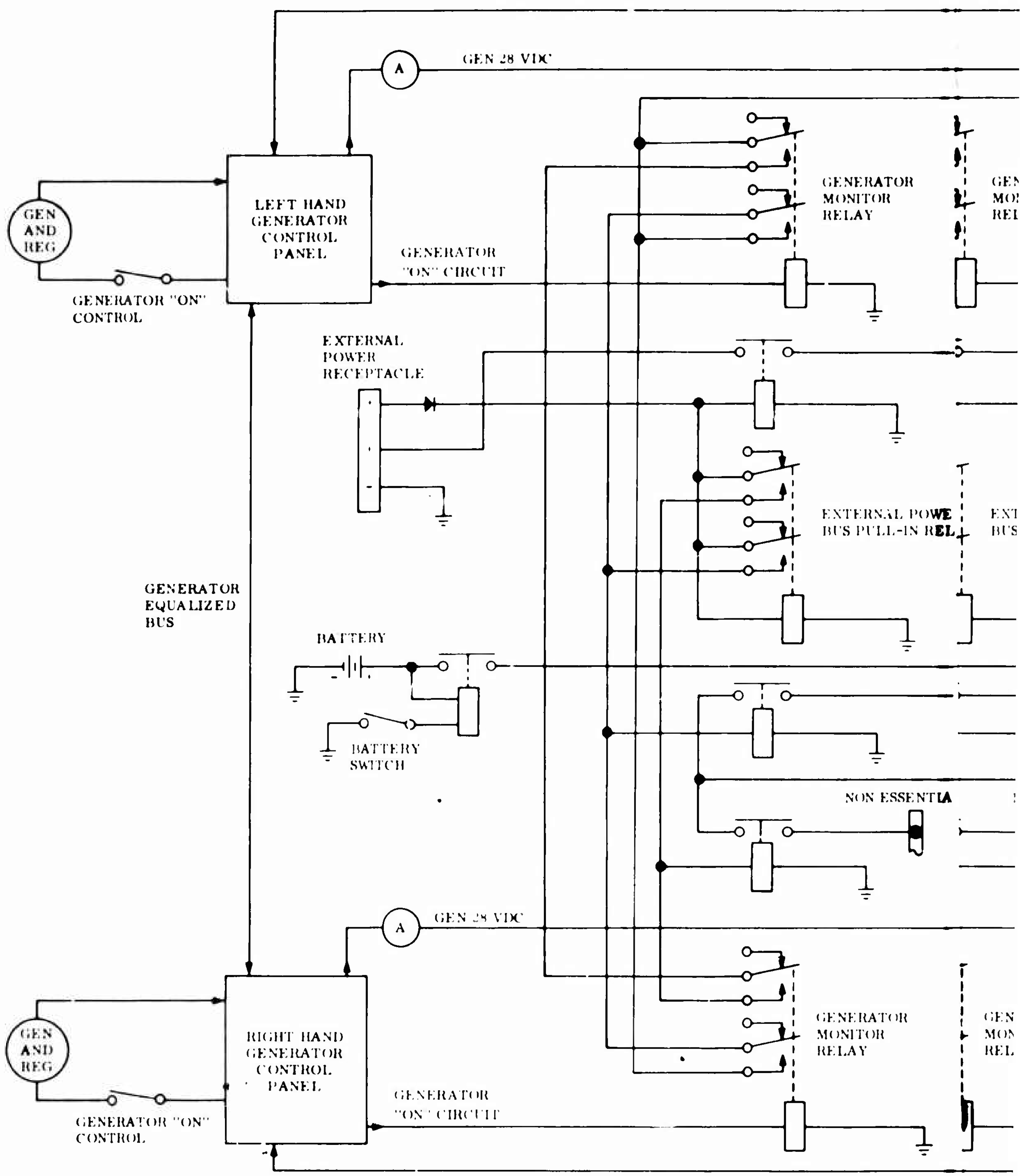
3.15.2 Navigation Subsystem. - Not applicable.

3.15.3 Identification Subsystem. - Not applicable.

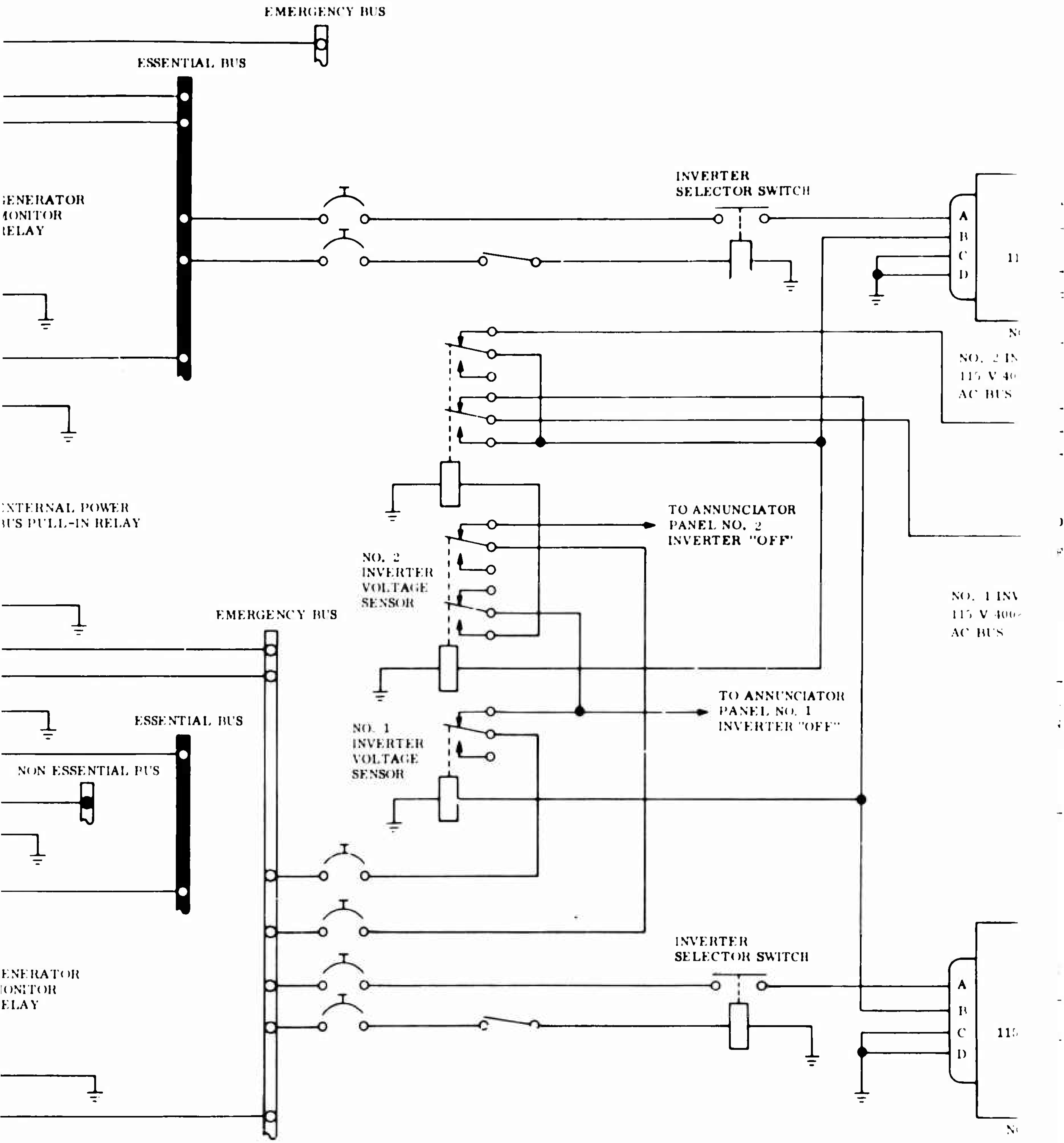
3.16 Reconnaissance Subsystems. - Not applicable.

3.17 Fire-Power Control Subsystems. - Not applicable.

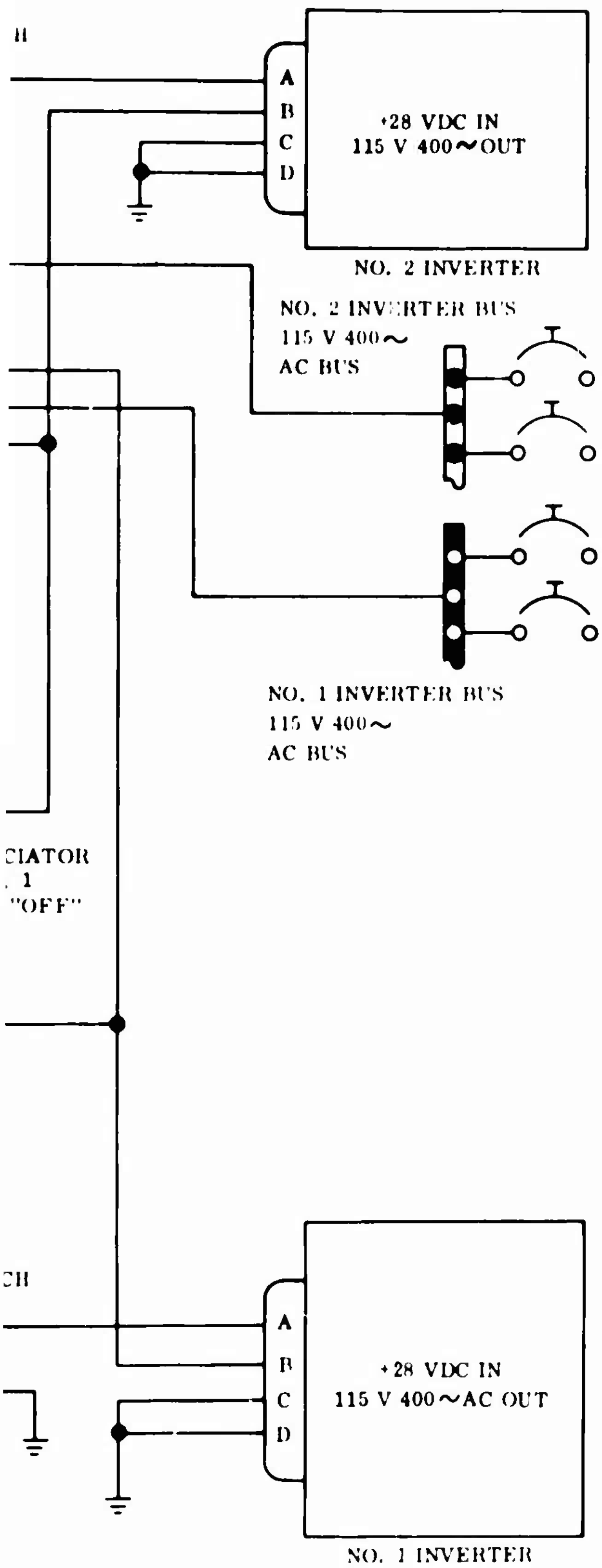
3.18 Armament Subsystems. - Not applicable


GEN 28 VDC
GEN AND REG
LEFT HAND GENERATOR CONTROL PANEL
GENERATOR "ON" CONTROL
GENERATOR "ON" CIRCUIT
GENERATOR MONITOR RELAY
EXTERNAL POWER RECEPTACLE
EXTERNAL POWE
BUS PULL-IN REL
GENERATOR EQUALIZED BUS
BATTERY
BATTERY SWITCH
NON ESSENTIA
GEN 28 VDC
GEN AND REG
RIGHT HAND GENERATOR CONTROL PANEL
GENERATOR "ON" CONTROL
GENERATOR "ON" CIRCUIT
GENERATOR MONITOR RELAY

A


EMERGENCY BUS
ESSENTIAL BUS
GENERATOR MONITOR RELAY
INVERTER SELECTOR SWITCH
A
B
C
D
NO. 2 IN
115 V 40
AC BUS
EXTERNAL POWER BUS PULL-IN RELAY
TO ANNUNCIATOR PANEL NO. 2 INVERTER "OFF"
NO. 2 INVERTER VOLTAGE SENSOR
EMERGENCY BUS
NO. 1 INV
115 V 400
AC BUS
TO ANNUNCIATOR PANEL NO. 1 INVERTER "OFF"
ESSENTIAL BUS
NO. 1 INVERTER VOLTAGE SENSOR
NON ESSENTIAL BUS
ENERATOR ONITOR ELAY
INVERTER SELECTOR SWITCH
A
B
C
D

B



28 VDC

NON-ESSENTIAL BUS LOADS

FLIGHT TEST INSTRUMENTATION

ESSENTIAL BUS LOADS

NO. 2 INVERTER
AILERON TRIM ACTUATOR
RUDDER TRIM ACTUATOR
PITCH FAN TRIM ACTUATOR
ROLL TRIM ACTUATOR, FAN
YAW TRIM ACTUATOR, FAN
TRIM POSITION INDICATOR, FAN

EMERGENCY BUS LOAD

RADIO
FUEL SYSTEMS
FIRE AND OVERHEAT DETECTOR SYSTEM
LANDING GEAR CONTROL SYSTEM
NO. 1 INVERTER
FLAP ACTUATOR
FLAP POSITION INDICATOR
THRUST SPOILER CONTROL
THRUST SPOILER POSITION INDICATOR
THRUST VECTOR ACTUATOR
THRUST VECTOR POSITION INDICATOR
HORIZONTAL STABILIZER CONTROL VALVES
HORIZONTAL STABILIZER POSITION INDICATOR
PITCH FAN INLET LOUVER ACTUATORS
FAN DOOR LATCH ACTUATORS
STABILIZATION AUGMENTATION SYSTEMS
FAN SPEED INDICATOR AND CONTROL
CONVERSION CONTROL SYSTEMS
DIVERTER CONTROL VALVES

115 V 400 ~ AC

NO. 1 INVERTER BUS LOADS

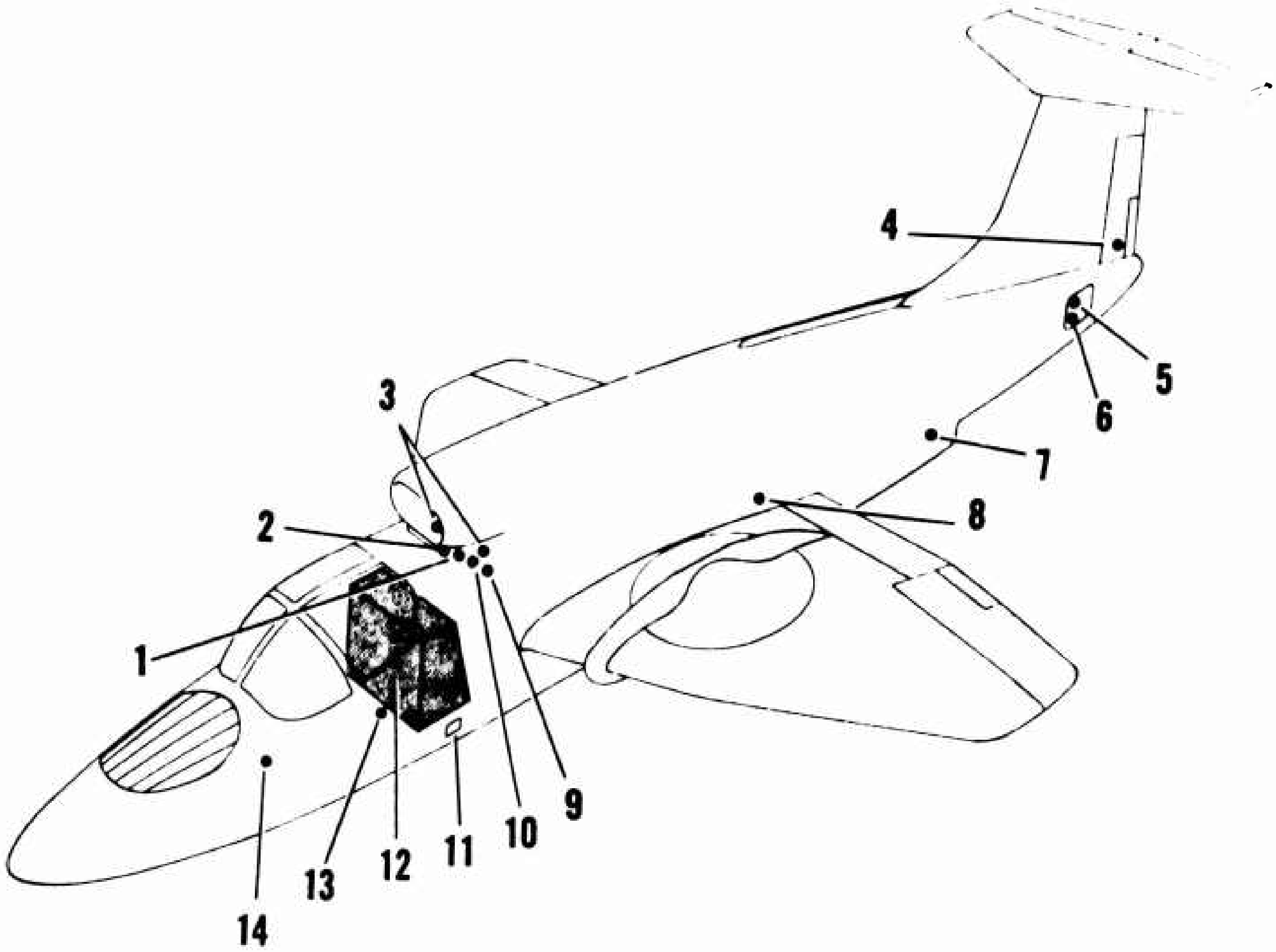
IGNITION
STABILIZATION AUGMENTATION SYSTEMS
OIL PRESSURE
HYDRAULIC PRESSURE

NO. 2 INVERTER BUS LOADS

FLIGHT TEST INSTRUMENTATION
ENGINE ANTI-ICE
FUEL FLOW
ATTITUDE INDICATOR

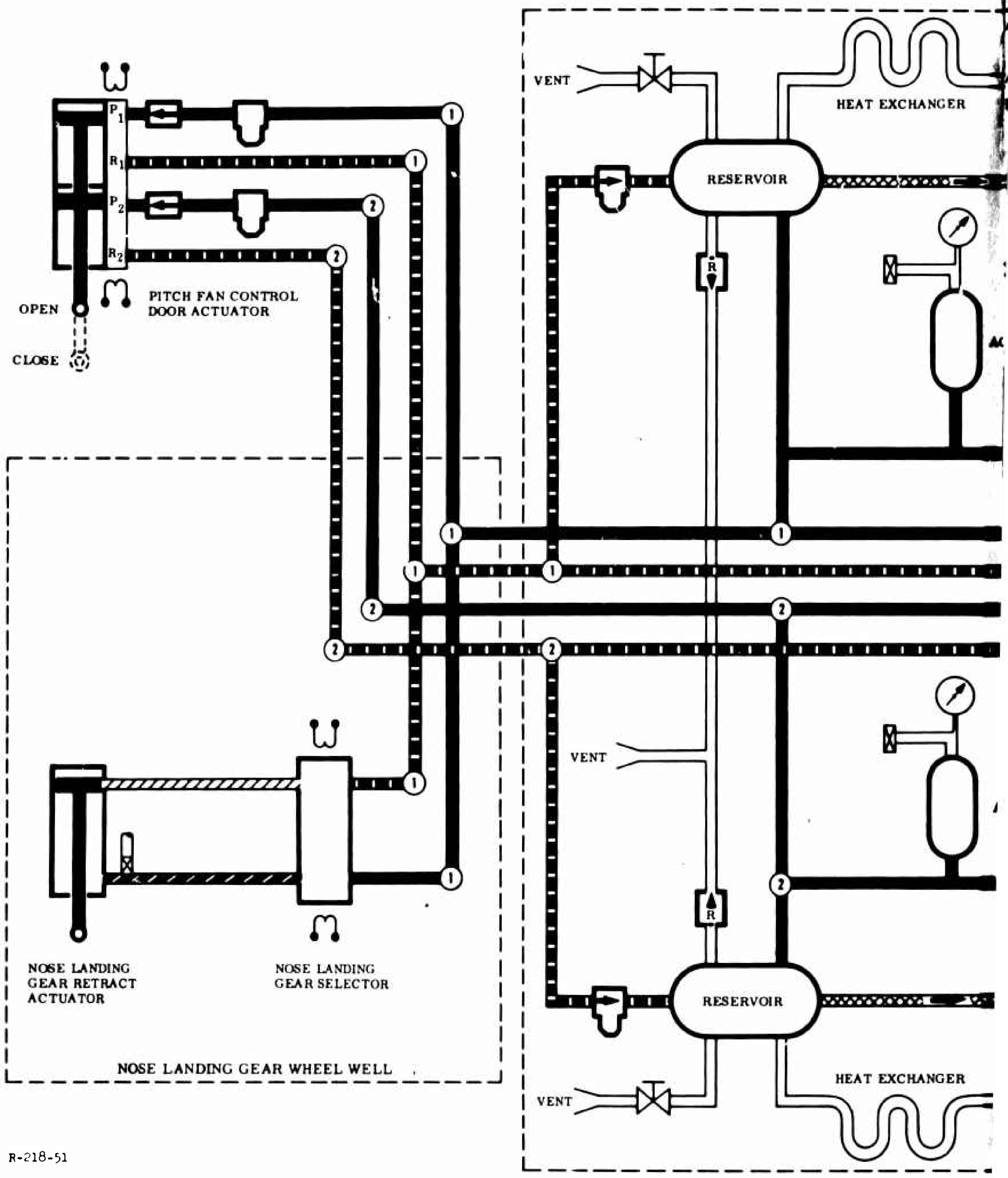
Figure 17 Electrical Power Distribution System Schematic Diagram

C



1. Louver Roll Trim Actuator
2. Louver Yaw Trim Actuator
3. Generators
4. Rudder Trim Tab Actuator
5. Battery
6. Inverters
7. Thrust Spoiler Actuator
8. Flap Actuator
9. Louver Vectoring Actuator
10. Electrical Flight Control Mixer Box
11. External Power Receptacle
12. Electrical Equipment Compartment
13. Nose Fan Pitch Trim Actuator
14. Nose Fan Inlet Door Actuator

Figure 48 Electrical System Component Location Diagram



VENT
HEAT EXCHANGER
RESERVOIR
PITCH FAN CONTROL DOOR ACTUATOR
OPEN
CLOSE
VENT
NOSE LANDING GEAR RETRACT ACTUATOR
NOSE LANDING GEAR SELECTOR
RESERVOIR
NOSE LANDING GEAR WHEEL WELL
VENT
HEAT EXCHANGER

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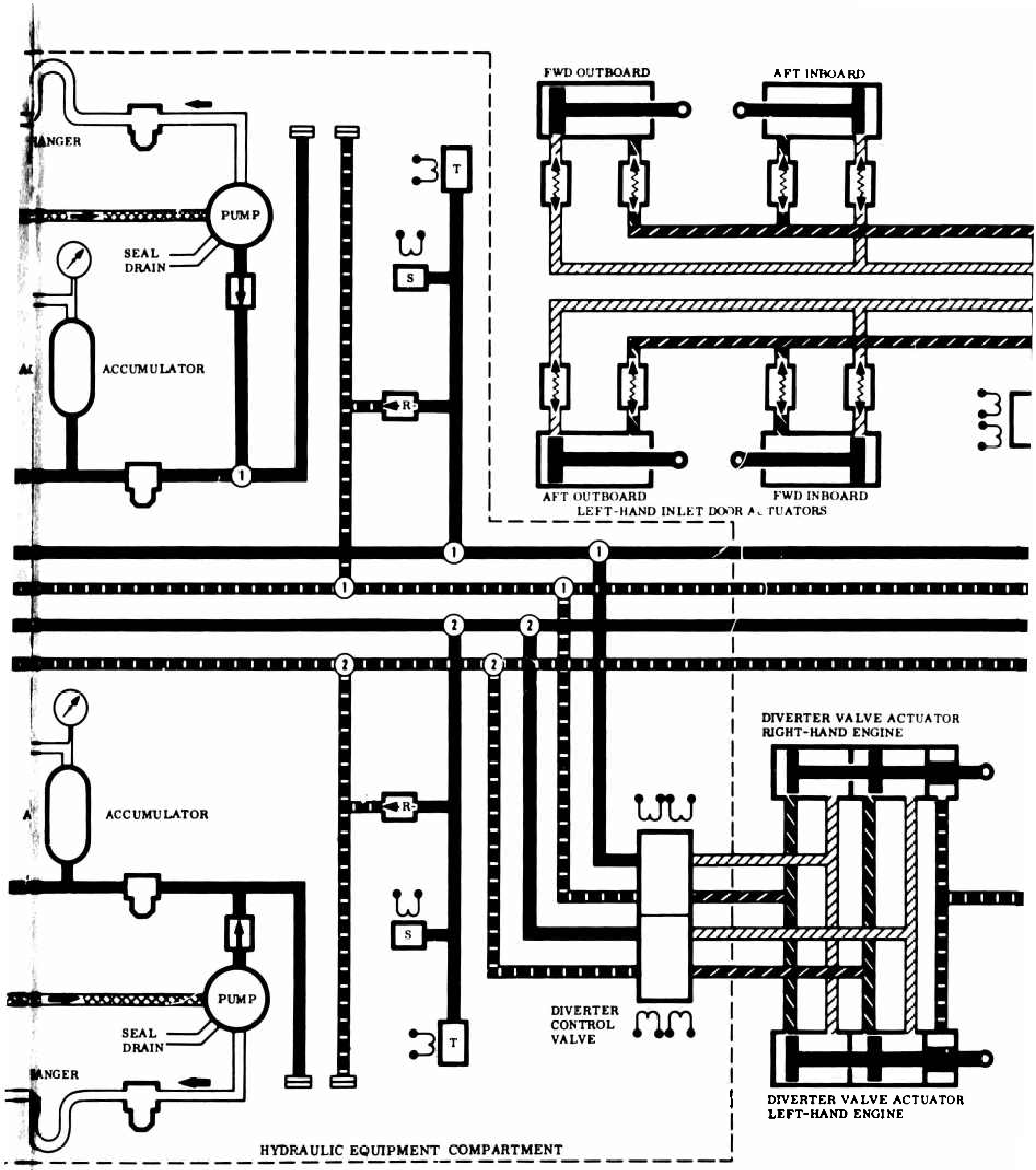
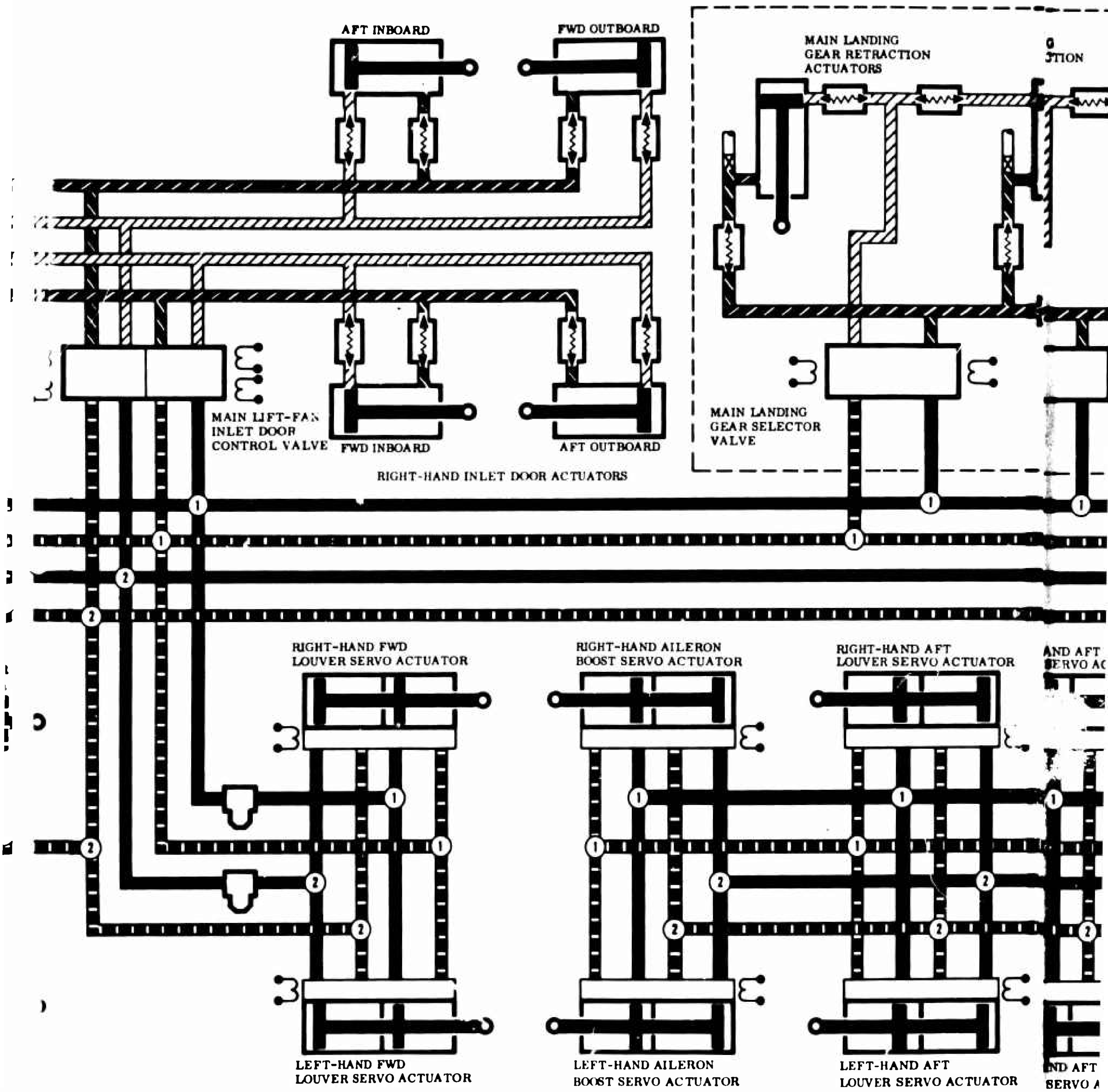
A



FWD OUTBOARD
AFT INBOARD
ANGER
PUMP
SEAL
DRAIN
ACCUMULATOR
T
S
R
AFT OUTBOARD
FWD INBOARD
LEFT-HAND INLET DOOR ACTUATORS
1
2
DIVERTER VALVE ACTUATOR
RIGHT-HAND ENGINE
ACCUMULATOR
DIVERTER
CONTROL
VALVE
PUMP
SEAL
DRAIN
ANGER
DIVERTER VALVE ACTUATOR
LEFT-HAND ENGINE
HYDRAULIC EQUIPMENT COMPARTMENT

B



AFT INBOARD
FWD OUTBOARD
MAIN LANDING
GEAR RETRACTION
ACTUATORS
MAIN LIFT-FAN
INLET DOOR
CONTROL VALVE
FWD INBOARD
AFT OUTBOARD
RIGHT-HAND INLET DOOR ACTUATORS
MAIN LANDING
GEAR SELECTOR
VALVE
RIGHT-HAND FWD
LOUVER SERVO ACTUATOR
RIGHT-HAND AILERON
BOOST SERVO ACTUATOR
RIGHT-HAND AFT
LOUVER SERVO ACTUATOR
LEFT-HAND FWD
LOUVER SERVO ACTUATOR
LEFT-HAND AILERON
BOOST SERVO ACTUATOR
LEFT-HAND AFT
LOUVER SERVO ACTUATOR

C

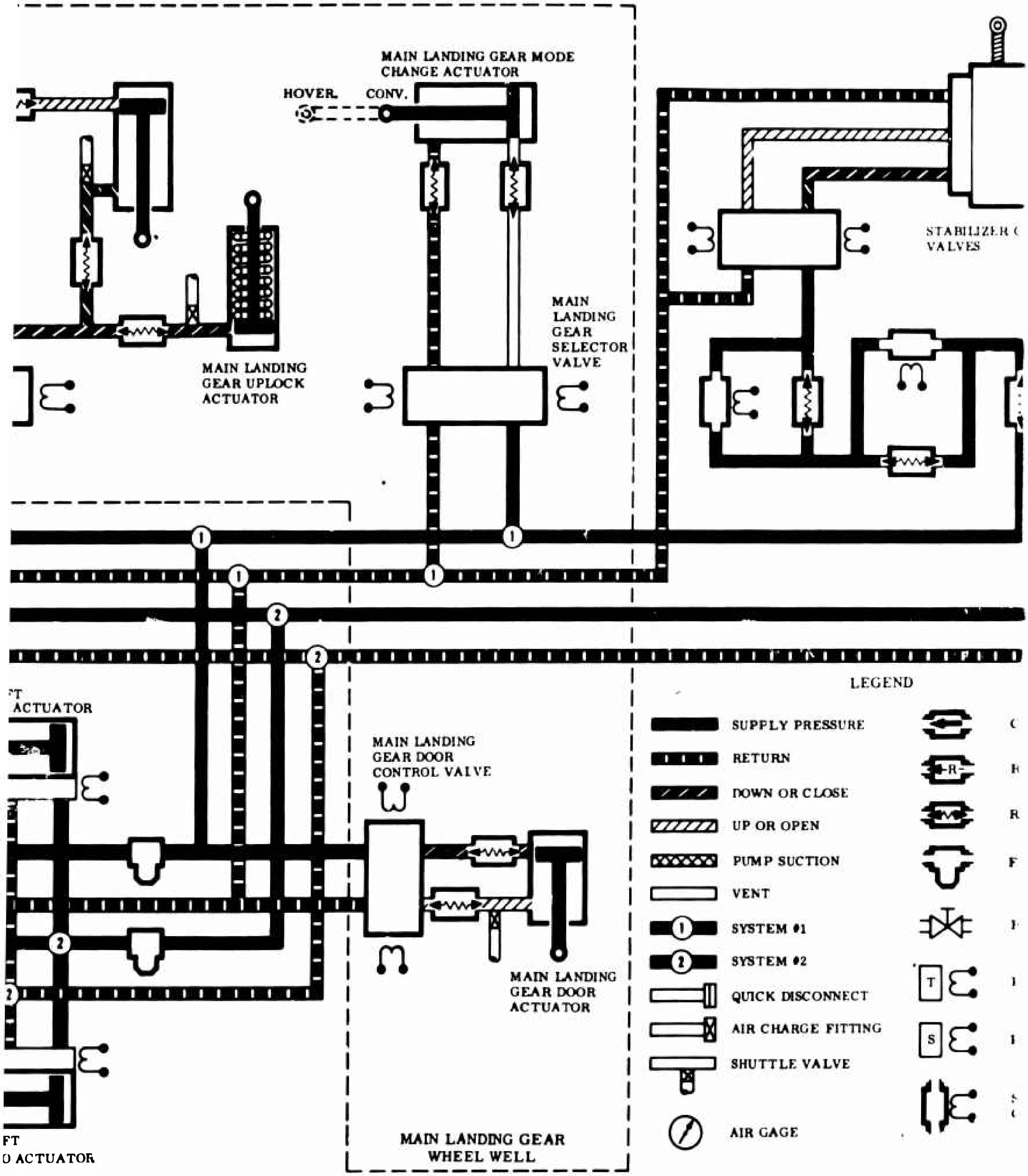


Figure 49 Aircraft Hydraulic System

D

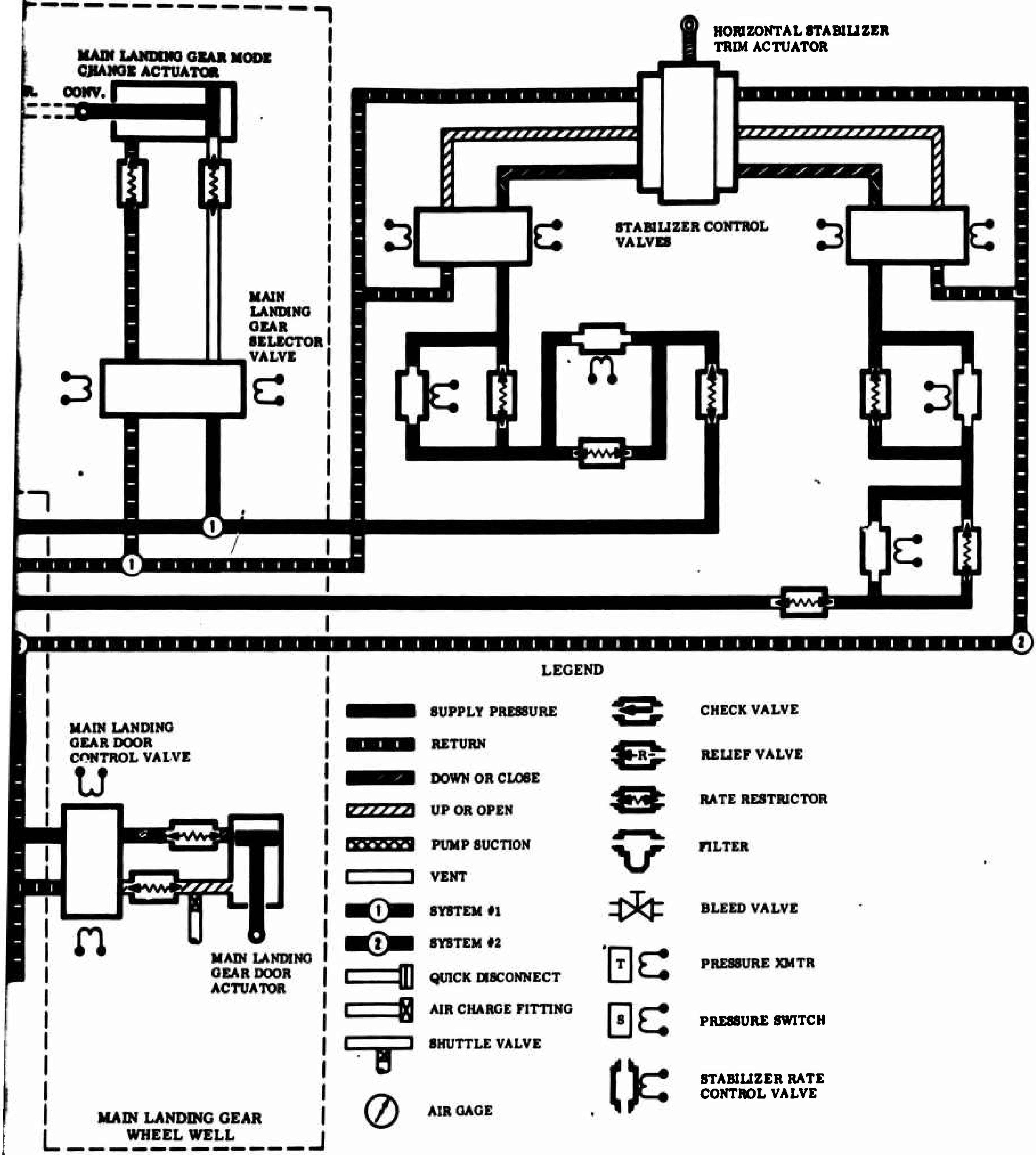
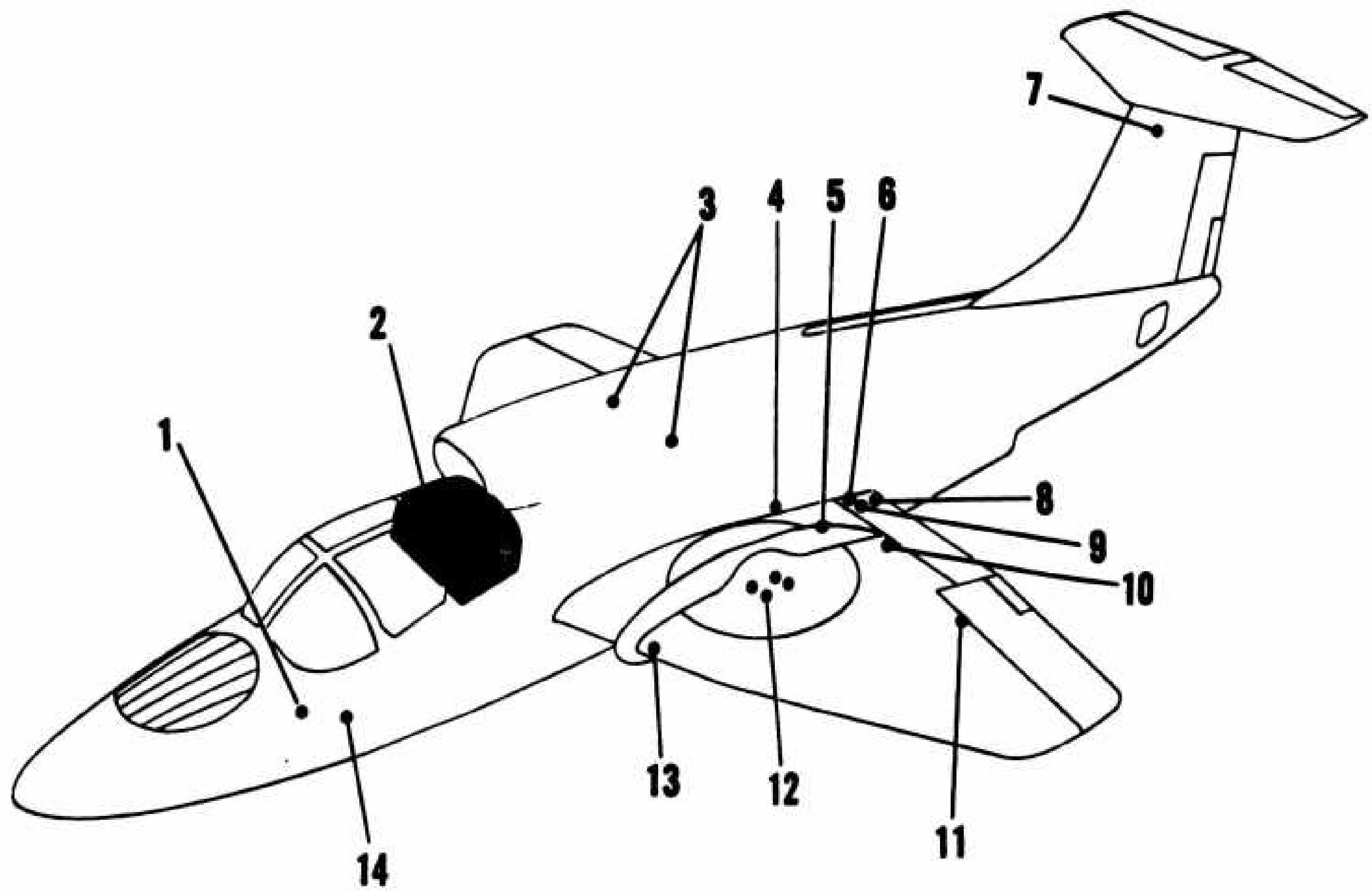
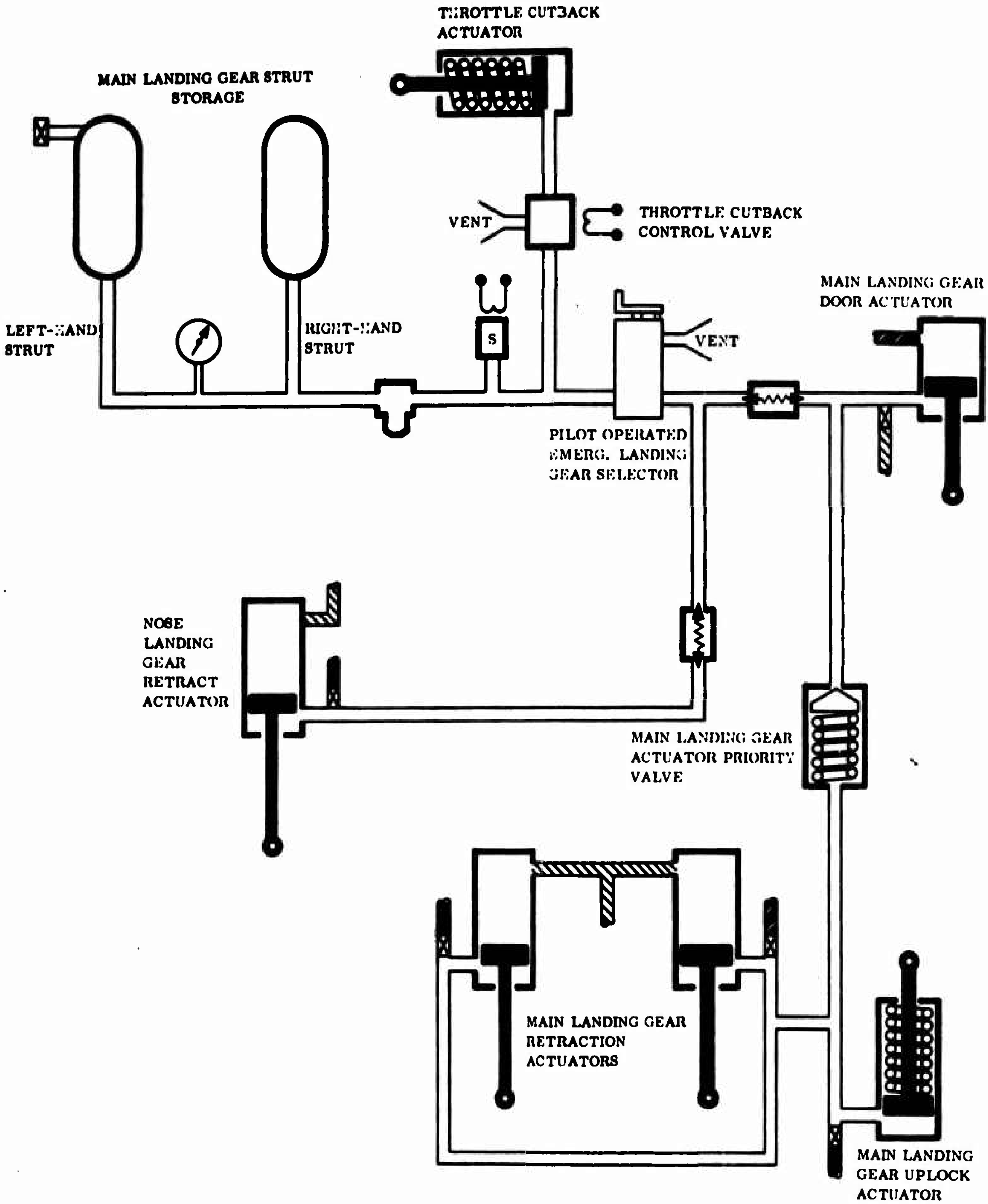


Figure 49 Aircraft Hydraulic System Schematic Diagram



1. Pitch Control Door Actuator
2. Hydraulic Equipment Compartment
3. Diverter Valve Actuator
4. Right Hand Main Landing Gear Retract Actuator (MLG Wheel Well)
5. Left Hand Main Landing Gear Retract Actuator (MLG Wheel Well)
6. Main Landing Gear Uplock Actuator
7. Horizontal Stabilizer Trim Actuator
8. Main Landing Gear Door Actuator (Left hand side only, MLG Wheel Well)
9. Main Landing Gear Mode Change Actuator (on centerline of airplane) MLG Wheel Well)
10. Left Hand Aft Exit Louver Actuator
11. Left Hand Aileron Boost Servo Actuator
12. Left Hand Main Lift Fan Inlet Door Actuator (4)
13. Left Hand Forward Exit Louver Actuator
14. Nose Landing Gear Retract Actuator (Nose Wheel Well)

R-210-49 Figure 50 Hydraulic System Component Location Diagram



R-218-52 **Figure 51 Aircraft Emergency Pneumatic System Schematic Diagram**

3.19 Cargo and Transport Subsystems. - Not applicable.

3.20 Countering Subsystems. - Not applicable.

3.21 Ground Handling and Servicing Provisions. -

3.21.1 Towing Provisions. - Provisions shall be made to forward tow the aircraft by the nose wheel. Nose wheel design shall accommodate towing speeds of 20 MPH maximum over smooth hard surfaces, and 3 MPH maximum over soft surfaces.

3.21.2 Jacking Provisions. - Provisions shall be included for jacking of the wings and fuselage. Jack points shall be provided on each main landing gear.

3.21.3 Mooring and Holdback Provisions. - Tie-down lugs shall be provided to accommodate aircraft mooring. Removable holdback fittings for engine thrust tests shall be provided.

3.21.4 Hoisting Provisions. - Provisions shall be included for hoisting the entire aircraft, and major subassemblies.

3.21.5 Handling Provisions. - Dollies shall be provided by the prime contractor for handling and maintenance of engine, and, wing and nose fan assemblies.

3.21.6 Covers. - Covers shall be provided for environmental protection of the cockpit canopy, engine inlets and exits, pitot mast, and exposed openings.

3.21.7 Hydraulic Test Equipment. - Hydraulic test equipment shall be provided for test and operation of hydraulic controls, and individual hydraulic components.

3.21.8 Miscellaneous Servicing Equipment. - Miscellaneous servicing equipment for ground handling and checkout shall be provided as required.

3.22 Aerial Resupply Subsystems. - Not applicable.

3.23 Air Rescue Subsystems. - Not applicable.

3.24 Range Extension Subsystems. - Not Applicable

3.25. Air Weather Subsystems. - Not applicable.

3.26 Preflight Readiness Checkout Provisions. - Provisions shall be incorporated to permit thorough preflight readiness checkout of the aircraft.

4. QUALITY ASSURANCE PROVISIONS. -

4.1 Unless otherwise specified by the procuring activity, inspection methods and tests shall be performed using specification MIL-Q-9858 as a guide. Specific aircraft subsystems shall be inspected as outlined by applicable specifications.

5. PREPARATION FOR DELIVERY. -

5.1 The aircraft shall be prepared for delivery to Edwards Air Force Base, California, for flight test.

6. NOTES. -

6.1 Intended Use. - This specification is intended to describe the aircraft to be supplied under terms of the contract.

APPENDIX "A"

FLYING QUALITIES REQUIREMENTS

Ryan Report #62B062

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LIST OF ILLUSTRATIONS

LIST OF TABLES

1.0 INTRODUCTION. -

1.1 Scope. - This specification contains design requirements for the flying qualities of the U. S. Army XV-5A Flight Research Aircraft. The specification consists of a consolidation of the applicable requirements given in Military Specification MIL-F-8785 (ASG) Amendment-4, Flying Qualities of Piloted Airplanes, as amended by the U. S. Army in RFQ TREC-RC Annex C, 31 March 1961; Military Specification MIL-H-8501A, Helicopter Flying and Ground Handling Qualities, General Requirements for, as amended by the U. S. Army; and additional requirements for stability and control specified by the U.S. Army and given in Ryan Report 61B049 Revision B, 29 May 1961.

1.2 For purposes of this specification, the aircraft shall be considered to have an operational envelope made up of two distinct parts: (a) lift-fan and (b) conventional. The lift-fan portion of the envelope shall encompass aircraft operation where all or any part of the sustention and/or propulsion of the aircraft is derived from the lift-fan system. This shall include hovering, vertical flight, transition flight, taxi, and short take-off and landing operations with the aircraft in the lift-fan mode. The conventional portion of the operational envelope shall encompass all operations where the basic gas generator provides the sole means of propulsion, and, in flight, the aircraft is supported entirely by aerodynamic forces generated on the external surface of the aircraft.

2.0 APPLICABLE DOCUMENTS. - None.

3.0 REQUIREMENTS. -

3.1 General. -

3.1.1 Characteristics. - Section 3 contains requirements for the flying qualities of the aircraft in the two operational modes, and for certain relevant ground handling characteristics. As directed by the U. S. Army, flying quality requirements given herein were derived fundamentally from flying qualities specifications for two different types of aircraft. It cannot be assumed that the requirements so obtained will in all cases prove most desirable when consideration is given to the inherent flight characteristics of the aircraft. Because of this, where conflicts arise between requirements given herein and the aircraft characteristics considered acceptable or desirable, effort shall be extended during the aircraft design for pilot evaluation of the requirement and the aircraft characteristic, to establish a level of relative acceptability, making use of flight simulation if required. In particular, it is to be expected that certain requirements specified for lift-fan operation will require special study to establish acceptability for the aircraft. In addition, every effort shall be made during the design phase of the aircraft to provide desirable characteristics in those areas not specifically covered by the specification.

3.1.2 Aircraft Loadings. - An envelope of cg (center of gravity) position versus gross weight shall be established for the aircraft. This envelope shall encompass all combinations of gross weight and cg positions that could reasonably be expected or permitted during the projected flight research testing of the aircraft. Unless otherwise specified, the requirements of section 3 shall apply at all combinations of gross weight and center of gravity depicted in the cg envelope. In general, compliance with this stipulation may be established by investigation of the weight and center of gravity condition considered to be most critical.

3.1.3 Altitudes. - Unless otherwise stated, the requirements shall apply at all altitudes at which the aircraft might be operated in each of the specified configurations. In general, compliance with this stipulation may be determined by investigation of altitudes consistent with the flight research testing of the aircraft. These altitudes for conventional operation shall be defined as follows:

(a) Low altitude: Sea level

(b) High altitude: An altitude not lower than 80 per cent of the maximum operational altitude.

(c) Medium altitude: Approximately 50 per cent of high altitude or 40,000 feet, whichever is lower.

The high and medium altitude conditions may be excluded in consideration of configurations L, PA, WO, and TO in investigation of flight in the conventional mode (see paragraph 3.1.8 for definition of configurations). Investigations of flight in the lift-fan mode may be limited to one altitude.

3.1.4 Operational Flight Envelopes. - Operational flight envelopes shall be established for each of the two flight modes of the aircraft as described below. These operational flight envelopes shall be considered minimum and shall define boundaries within which the aircraft is expected to be operational and within which the requirements of this specification therefore apply. Within these boundaries there shall be no objectionable buffet, trim, or stability changes, or other irregularities which might detract from the effectiveness of the aircraft in executing its intended mission.

3.1.4.1 The lift-fan operational envelope shall encompass all pertinent translational requirements given in paragraphs 3.3 and 3.5. The symmetrical flight envelope, unless limited structurally, shall extend from zero normal acceleration or the minimum normal

acceleration achievable from trimmed level flight through normal use of control (whichever is greater) to the maximum attainable normal acceleration. As a minimum, unless limited by structural considerations, the envelope shall extend to the maximum horizontal flight speed achievable in the lift-fan mode, and shall encompass the maximum altitude consistent with the flight research testing of the aircraft in this mode.

3.1.4.2 The conventional operational envelope shall be developed from the aircraft structural design normal load factor envelopes shown in figure 1, and except for flaps extended, shall encompass the maximum operational altitude of the aircraft. The flight speed V_M (or M_M) envelope shall as a minimum extend to the maximum horizontal flight speed (V_H) attainable during conventional operation (figure 2), but shall not exceed the structural limit speed (V_L). The operational envelope shall coincide in normal acceleration with the structural design envelope up to and including the maximum operational speed. For flaps extended, the operational envelope shall coincide in altitude with that of the lift-fan envelope. For weights greater than the design gross weight, limit positive and negative load factors shall be those which provide constant gross weight load factor products when applying the limit load factors at the design gross weight.

3.1.5 Maximum Permissible Speed Envelope. - A maximum speed V_D (or M_D) altitude envelope shall be established for conventional operation. This maximum permissible speed envelope shall be derived from consideration of dives entered at V_H. Unless limited by structural considerations, this envelope shall define, at each altitude, the maximum speed from which a recovery can be made which will result in level flight at an altitude of not less than 2,000 feet above sea level without encountering intolerable buffet, loss of control, uncontrollable trim changes, or other dangerous aircraft

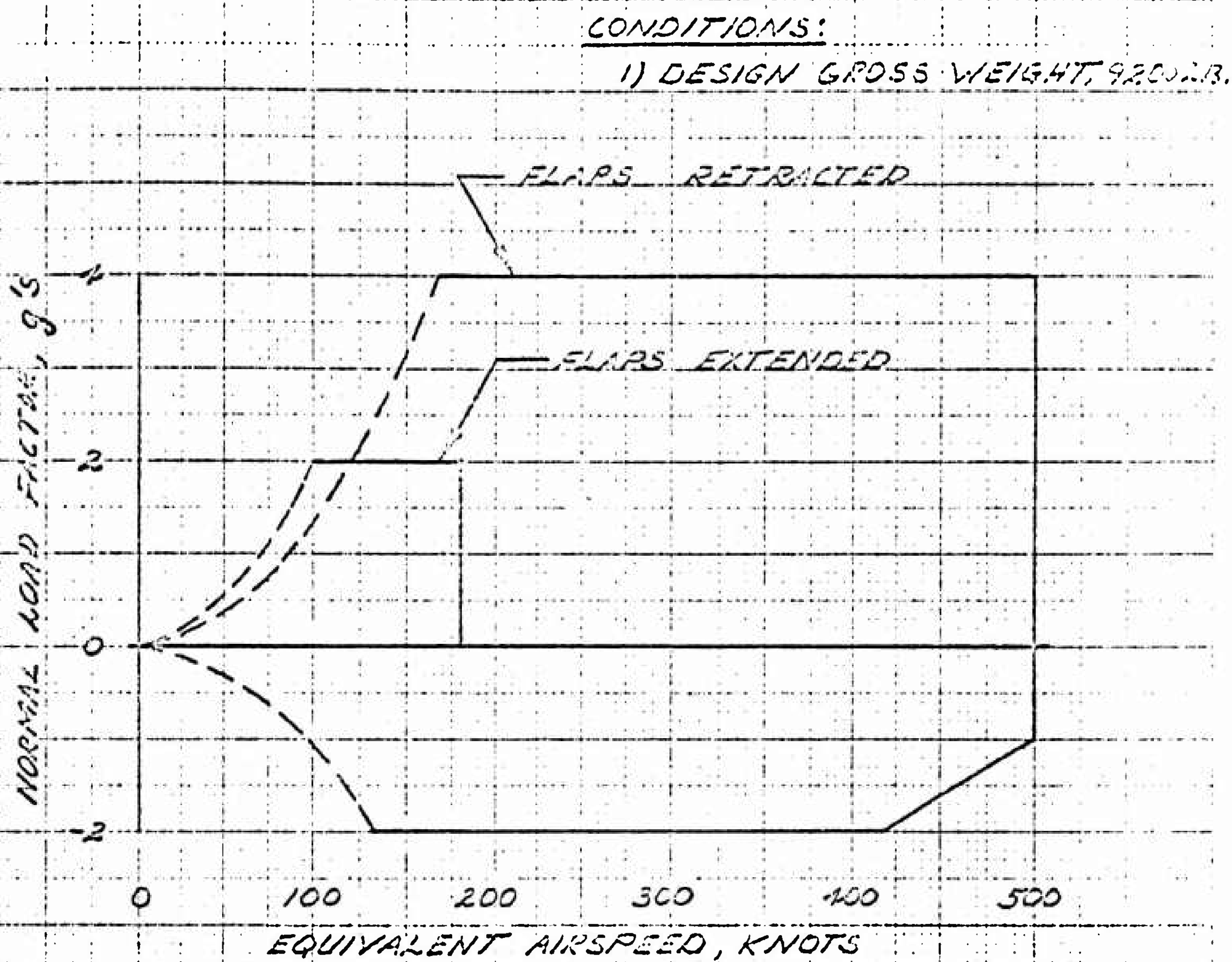

Figure 1. Conventional Flight Structural Design
Normal Load Factor Envelope

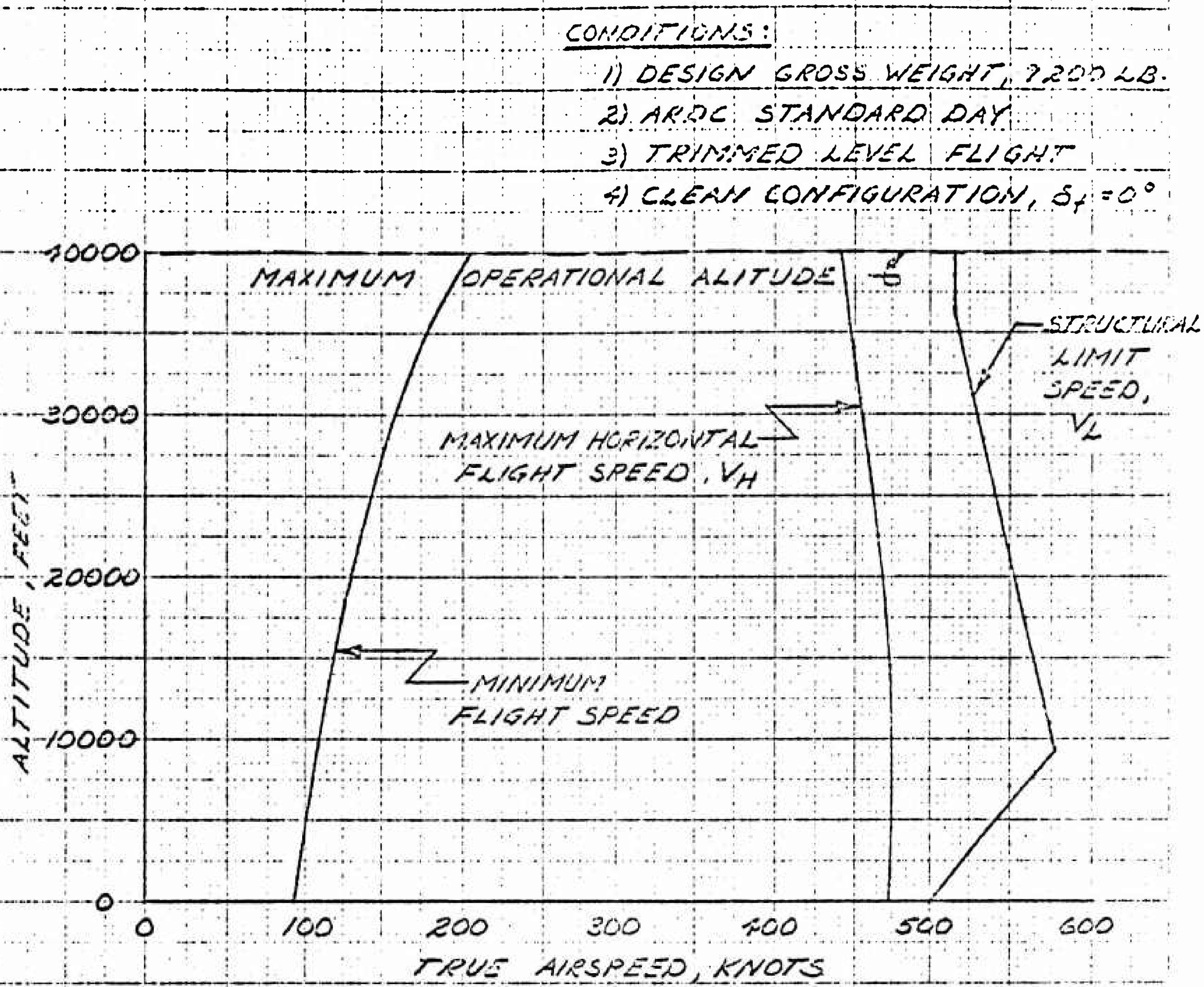

Figure 2. Speed Altitude Envelope

behavior during the entire dive or pullout. In establishing this maximum permissible speed, the pullout shall be governed by the requirements of paragraph 3.4.15.

3.1.5.1 The development of any dangerous flight conditions associated with the dive or pullout described in paragraph 3.1.5 shall be sufficiently gradual to provide ample warning to the pilot of the impending condition.

3.1.6 Deceleration Devices. - The term "deceleration device" referred to in this specification shall apply to the drag parachute which has been provided solely for emergency use to enable rapid descent and deceleration at high speed.

3.1.7 Effects of Asymmetry. - There shall be no dangerous or seriously objectionable flight characteristics resulting from asymmetric flight conditions which may be encountered in normal operations (e.g., unequal flap or thrust spoiler operation, manufacturing tolerances, misalignment of tailpipe nozzles, etc.).

3.1.8 Configurations. - For purposes of this specification, the basic aircraft configurations shall be as described herein. Items of configuration not specified shall be in their normal settings for the particular configuration.

Configuration CR:	Cruise: Power for level flight at trim speed (see Table III), flaps in cruise position, gear up.
Configuration D:	Dive: 25 per cent normal rated power or minimum operable power whichever is greater, flaps and gear up.
Configuration G:	Glide: Power off, unless otherwise specified; gear and flaps up.
Configuration L:	Landing: Power off, gear down, flaps at landing setting.

Configuration P: Power on, clean: Normal rated power, flaps and gear up.

Configuration PA: Power Approach: Gear down, flaps in normal approach position; power for level flight at 1.15 V_{S_L} or normal approach speed, whichever is lower.

Configuration WO: Wave Off: Gear down, flaps in landing position, takeoff power.

Configuration TO: Takeoff: Gear down, flaps at takeoff setting, takeoff power.

3.2 Mechanical Characteristics of Control Systems. -

3.2.1 Control Friction and Breakout Force. - Longitudinal, lateral, and directional controls shall exhibit positive centering in flight at any normal trim setting. Although absolute centering is not required, the degree of centering shall be such that the combined effects of centering, breakout force, stability of the aircraft and force gradients do not produce objectionable flight characteristics, or permit large departures from trim conditions with controls free. With the controls trimmed for zero forces, the breakout forces, including friction, feel, preload, etc., shall be within the values given in table I. These values refer to the pilot control force required to start movement of the control surface at any attainable trimmed flight condition. Cockpit control "jump", when trim is actuated, is undesirable.

3.2.1.1 Measurement of the breakout forces on the ground will ordinarily suffice in lieu of actual flight measurements, provided that qualitative agreement between ground measurement and flight observation can be demonstrated.

TABLE I

Allowable Breakout Forces (including friction), Pounds

Control	Minimum	Maximum
longitudinal	1/2	1.5
lateral	1/2	1.5
directional	3 *	7
height	1 *	3

* May be measured with adjustable friction set.

3.2.1.2 The height control shall remain fixed at all times unless it is moved by the pilot, and shall be essentially irreversible so that it will not creep. The maximum effort for stick and throttle-type controls shall not exceed seven pounds and three pounds, respectively.

3.2.1.3 For emergency manual operation upon failure of a power-operated or power-boosted control system, the allowable breakout forces specified in table I may be doubled.

3.2.2 Adjustable Controls. - When a cockpit control is adjustable for pilot physical dimensions or comfort, the control force as defined in paragraph 4.2 shall refer to the mean adjustment; a force referred to any other adjustment shall not differ by more than ten per cent from the force referred to the mean adjustment.

3.2.3 Rate of Control Displacement. - The ability of the aircraft to perform the maneuvers expected of it shall not be limited by the rates of control surface deflection or auxiliary control operation, nor shall the rates of operation of either primary controls or auxiliary devices result in objectionable flight characteristics.

3.2.4 Control System Free-play. - For all operating conditions there shall be no dead spots in any of the control systems which permit more than ± 0.2 inch motion of the cockpit control without corresponding motion of the control surfaces, etc.

3.2.5 Artificial Stability Devices. - Normal operation of an artificial device for improvement of any characteristic shall not introduce any objectionable flight or ground handling characteristics. Failure of such a device shall not result in a dangerous or intolerable flight condition (see paragraphs 3.9.4, 3.9.4.1, 3.9.4.2, 4.5 for additional discussion).

3.2.6 Mechanical Coupling in Control System. - For all operating conditions, longitudinal, lateral, directional, or height control motions shall not produce adverse response of the aircraft due to mechanical coupling in the control system. If mechanical intermixing of longitudinal, lateral, directional, or vertical control motions is required to achieve the requirements given herein, within the scope of paragraph 3.9.2, no adverse limitations in control power shall exist with any possible combination of control inputs throughout the entire range of each of the control motions due to this intermixing.

3.3 Longitudinal Stability and Control, Lift-fan Operation. -

3.3.1 Translational Flight. - It shall be possible to obtain smooth, steady flight over a speed range from at least 10 knots rearward to $V_{conversion}$. Throughout the specified speed range, a sufficient margin of control power in excess of that required for trim shall be available to control the effects of disturbances and shall be equal to at least 10 per cent of the maximum attainable pitching acceleration in hovering. Within the limits of speed specified, the controls and the aircraft itself shall be free from objectionable shake, vibration, and roughness as specified in paragraph 3.8.1.

3.3.2 Stability in Hovering Flight. - The aircraft shall be reasonably steady while hovering in still air (winds up to 3 knots), requiring a minimum movement of the pitch control to keep the machine over a given spot on the ground, for all terrain clearances up to the disappearance of ground effect. In any case, it shall be possible to accomplish this with less than ±1.0 inch movement of the pitch control.

3.3.3 Control Force Characteristics. - At all trim conditions and speeds specified in paragraph 3.3.1, the longitudinal force gradient for the first inch of travel from trim shall be no less than 0.5 pound per inch and no more than 2.0 pounds per inch. In addition, however, the force produced for a 1 inch travel from trim, by the gradient chosen shall not be less than the breakout force (including friction) exhibited in flight. There shall be no undesirable discontinuities in the force gradient, and the slope of the curve of stick force versus displacement shall be positive at all times with the slope for the first inch of travel from trim greater than or equal to the slope for the remaining stick travel.

3.3.4 Acceleration-deceleration Characteristics. - With the aircraft trimmed in hovering flight, it shall be possible to accelerate readily, safely, and rapidly to $V_{conversion}$ at constant altitude without encountering undesirable stalling or buffeting characteristics. From trimmed, steady, level, unaccelerated flight at the conversion speed, it shall be possible to decelerate readily, safely, and quickly to a stop and to hover at constant altitude. The ability to decelerate rapidly shall not be limited by longitudinal control power, longitudinal trim, stalling or buffeting, or engine thrust or response characteristics. The foregoing requirements apply both in and out of ground effect.

3.3.4.1 In order to provide flexibility of operation, it shall be possible to stop conversion or transition readily and safely in either direction. Rapidity of conversion or transition shall not be limited because of longitudinal stability and control characteristics or insufficient stall margin. This requirement is to apply both in ground effect and at the highest altitude

designated for transition. For safe operation, it is desirable at any time during transition to have landing capability within aircraft design strength with one engine inoperative.

3.3.4.2 It shall be possible to make steep descents to landing with adequate control of aircraft attitude and rate of descent without encountering undesirable stalling or buffeting characteristics. The ability to make steep descents shall not be limited because of engine power effects.

3.3.5 Trim Change. - Without retrimming, the longitudinal control forces required to change from any trim and power condition to any other trim and power condition, or for performance of the maneuvers discussed in paragraphs 3.3.4, 3.3.4.1, 3.3.4.2 and 3.9.1 or any other normal aircraft maneuvers, shall not exceed the values given in table II.

TABLE II

Limit control force values (pounds)
(when measured in flight with adjustable friction off)

Control	Limit Control Force
Longitudinal	8.0
Lateral	7.0
Height	7.0
Directional	15.0

3.3.6 Control Force Transients. - The controls shall be free from objectionable transient forces in any direction following rapid longitudinal stick deflections. During, and following rapid longitudinal displacement of the control stick from trim, the force acting in a direction to resist the displacement shall not

at any time fall to zero. Longitudinal control displacement shall not produce lateral control forces in excess of 20 per cent, or pedal forces in excess of 75 per cent of the associated longitudinal force. For aircraft employing power-boosted or power-operated controls, there shall be no lateral or directional control forces developed.

3.3.7 Control Response. - There shall be no objectionable or excessive delay in the development of angular velocity in response to control displacement. The angular acceleration shall be in the proper direction within 0.2 seconds after longitudinal control displacement. This requirement shall apply for the speed range specified in paragraph 3.3.1.

3.3.8 Speed Stability. - The aircraft shall, at all forward speeds, and at all trim and power conditions possess positive, static longitudinal control force and control position stability with respect to speed. This stability shall be apparent in that at constant throttle and height control settings, a rearward displacement of and a pull force on the longitudinal-control stick shall be required to hold a decreased value of steady, forward speed, and a forward displacement and a push force shall be required to hold an increased value of speed. In the speed range between 15 and 50 knots forward, and zero to 10 knots rearward, the same characteristics are desired, but a moderate degree of instability may be permitted. However, the magnitude of the change in the unstable direction shall not exceed 0.5 inch for stick position or 1.0 pound for stick force.

3.3.8.1 The stability requirements of paragraph 3.3.8 are intended to cover all steady flight conditions in which the aircraft might be operated for more than a short time interval. Level flight and various rates of descent at partial power to at least 500 fpm at the most critical cg position shall be considered.

3.3.8.2 The aircraft shall not exhibit excessive longitudinal trim changes with variations of rate of climb or descent at constant airspeed. Specifically, when starting from trim at any combination of power and airspeed within the flight envelope, it shall be possible to maintain longitudinal trim with a longitudinal control displacement of no more than 3 inches from the initial trim position as the engine power or height control or both are varied throughout the available range. Generally, the airspeeds needing the most specific investigation of the above characteristics include $V_{conversion}$ and the speeds between zero and one-half the speed for minimum power.

3.3.9 Dynamic Stability Characteristics. - The aircraft shall exhibit satisfactory dynamic stability characteristics following longitudinal disturbances in forward flight. Longitudinal oscillations with controls fixed following a disturbance shall exhibit the following characteristics:

(a) Any oscillation having a period of less than 5 seconds shall damp to one-half amplitude in not more than one cycle. There shall be no tendency for undamped small amplitude oscillations to persist.

(b) Any oscillation having a period greater than 5 seconds but less than 10 seconds shall damp to one-half amplitude in not more than two cycles. There shall be no tendency for undamped oscillations to persist.

(c) Any oscillation having a period greater than 10 seconds but less than 20 seconds shall be at least lightly damped.

(d) Any oscillation having a period greater than 20 seconds shall not achieve double amplitude in less than 20 seconds.

3.3.9.1 The following is intended to insure acceptable maneuver stability characteristics. Normal acceleration stipulations are intended to cover all speeds above that for minimum power required; angular velocity stipulations shall apply at all forward speeds including hovering:

(a) After the longitudinal control stick is suddenly displaced rearward a sufficient distance to generate a 0.2 radian/sec. pitching rate within 2 seconds, or a sufficient distance to develop a normal acceleration of 1.5g within 3 seconds, whichever is less, and then held fixed, the time-history of normal acceleration shall become concave downward within 2 seconds following the start of the maneuver, and remain concave downward until the attainment of maximum acceleration. Preferably, the time-history of normal acceleration shall be concave downward throughout the period between the start of the maneuver and the attainment of maximum acceleration. Figure 3 (a) is illustrative of the normal acceleration response considered acceptable.

(b) During this maneuver, the time-history of angular velocity shall become concave downward within 2.0 seconds following the start of the maneuver, and remain concave downward until the attainment of maximum angular velocity; with the exception that for this purpose a faired curve may be drawn through any oscillations in angular velocity not

in themselves objectionable to the pilot. Preferably, the time-history of angular velocity should be distinctly concave downward throughout the period between 0.2 second after the start of the maneuver and the attainment of maximum angular velocity. Figure 3 (b) is illustrative of the angular velocity response considered acceptable.

3.3.9.2 To insure that a pilot has reasonable time for corrective action following moderate deviations from trim attitude (as for example, owing to a gust), the effect of an artificial disturbance shall be determined. When the longitudinal control stick is suddenly displaced rearward from the trim, distance determined in paragraph 3.3.9.1 and held for at least 0.5 second and then returned to and held at the initial trim position, the normal acceleration shall not increase by more than 0.25g within 10 seconds from the start of the disturbance, except 0.25g may be exceeded during the period of control application. Further, during the subsequent nosedown motion (with the controls still fixed at trim) any acceleration drop below the trim value shall not exceed 0.25g within 10 seconds after passing through the initial trim value.

3.3.9.3 The response of the aircraft to motion of the longitudinal control shall be such that in the maneuver described in paragraph 3.3.9.1, the resulting normal acceleration always increases with time until the maximum acceleration is approached, except that a decrease not perceptible to the pilot may be permitted.

3.3.10 Hovering Control Power. - Longitudinal control power shall be such that when the aircraft is hovering in still air at the design gross weight (out of ground effect), a rapid 1.0 inch step displacement from trim of the longitudinal control shall produce

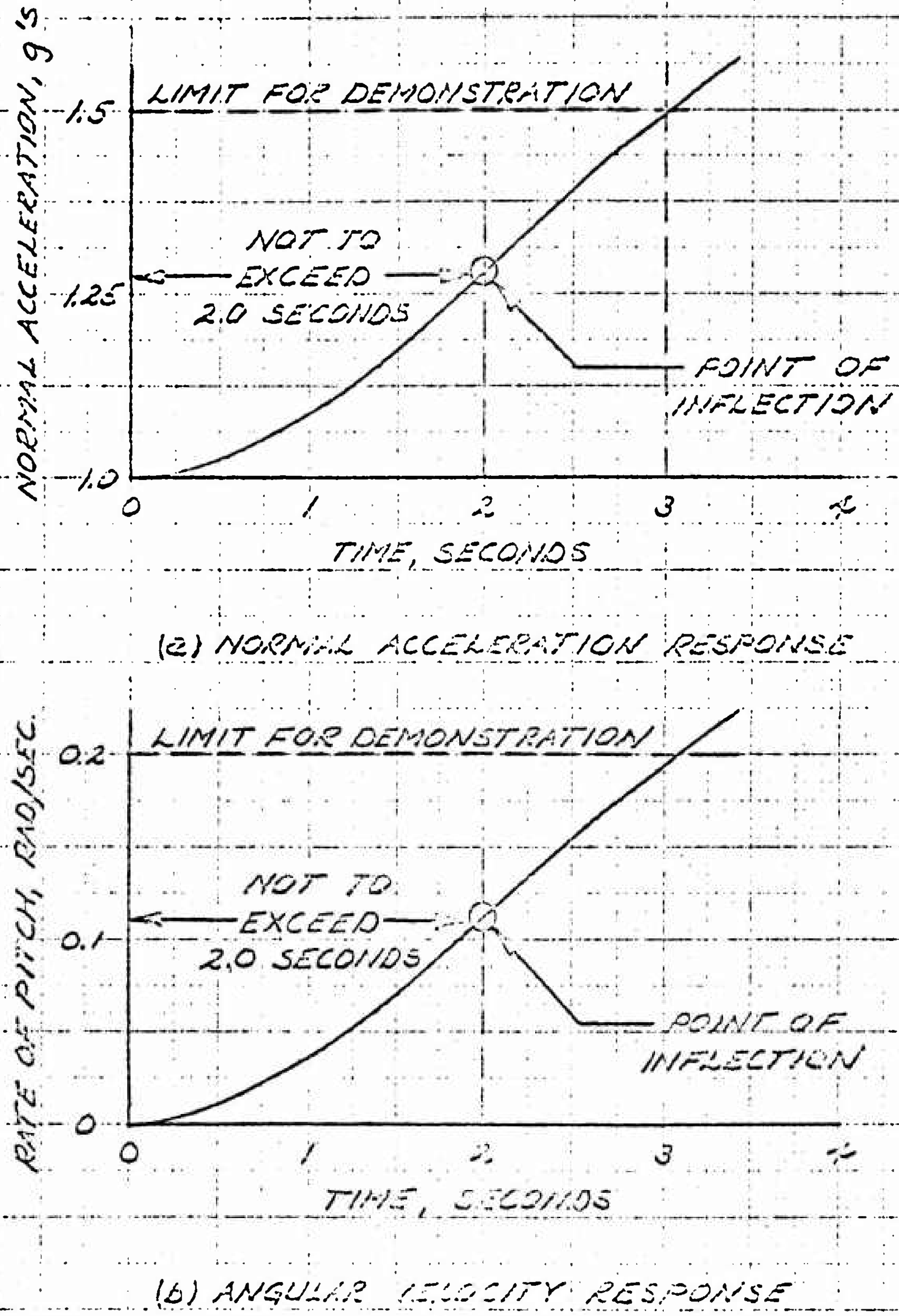

Figure 3. Typical Normal Acceleration and Pitch Rate Response (In this example the control input was limited by normal acceleration.)

an angular displacement at the end of 1.0 second, which is at least $73/(W + 1000)^{1/3}$ degrees. When maximum available displacement from trim of the longitudinal control is rapidly applied at the conditions specified above, the angular displacement at the end of 1.0 second shall be at least four times the angular displacement value given for 1.0 inch longitudinal control displacement. In the above expression, W represents the design gross weight of the aircraft in pounds.

3.3.11 Pitch Damping When Hovering. - To insure satisfactory initial response characteristics following a longitudinal control input and to minimize the effects of the external disturbances, the aircraft in hovering shall exhibit pitch angular velocity damping (that is, a moment tending to oppose the angular motion and proportional in magnitude to the angular velocity) of at least $15\ (I_y)^{0.7}$ ft. - lb./rad/sec, where I_y is the moment of inertia about the pitch axis expressed in slug-ft^2.

3.3.12 Control System Adjustability. - The longitudinal control system shall, in addition to providing the characteristics given above, permit the investigation in hovering flight of the effect of variation in control sensitivity, damping level, and control power. In particular, adjustability of damping level and stick sensitivity shall be provided to meet longitudinal control criteria given as desirable in Figure 4. The longitudinal control shall also be capable of generating a terminal angular velocity in pitch during hovering flight of 20 degrees per second. Further, the control system shall permit adjustment to reduced longitudinal control power and damping level to permit general investigation of aircraft handling qualities in hovering flight.

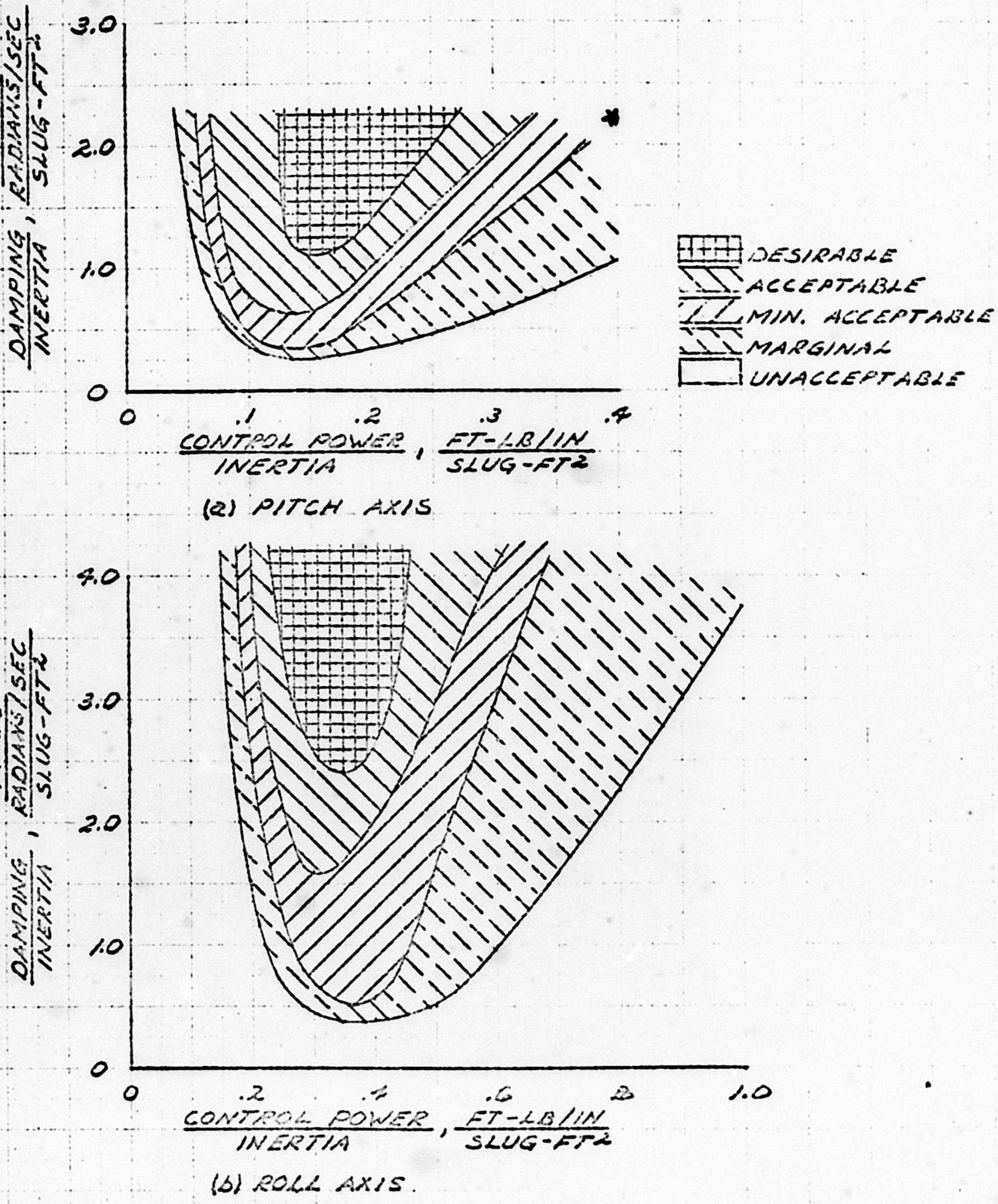

Figure 4. Longitudinal and Lateral Control Criteria

3.3.13 Short Takeoff and Landing Operation. - Short field takeoff and landing requirements shall be based on takeoff and landing operation over a 50 foot obstacle. Short field takeoff and landing speeds shall correspond to those speeds at which maximum STOL performance (minimum distance traveled) is achieved.

3.3.13.1 For takeoff, with trim optional but constant, the longitudinal control forces required for takeoff and the ensuing acceleration to the speed for minimum drag shall not exceed 20 pounds pull or 10 pounds push.

3.3.13.2 At the forward critical loading with the aircraft trimmed at the approach speed, the longitudinal control shall be suffiencitly effective to land the aircraft at the above designated landing speed with a longitudinal pull force not exceeding 20 pounds.

3.4 Longitudinal Stability and Control, Conventional Operation. -

3.4.1 Elevator-fixed Static Stability. - In the flight conditions and throughout the speed ranges listed in columns 1 and 2 of table III, the elevator-fixed neutral points shall be aft of the cg position in the aft critical loading.

3.4.1.1 At the aft critical loading, in the flight conditions and throughout the speed ranges listed in columns 1 and 2 of table III, the elevator-fixed static longitudinal stability with respect to angle of attack at constant speed shall be positive. This requirement shall also apply to configuration WO at 1.15 V_{S_L}.

3.4.2 Elevator-free Static Stability. - In the flight conditions and throughout the speed ranges listed in columns 1 and 2 of table III, the elevator-free neutral points shall be aft of the cg position in the aft critical loading. In general, this requirement shall be considered satisfied if the requirement of paragraph 3.4.2.1 is met. For configurations PA and P (climb), this requirement may be waived, provided paragraph 3.4.2.1 is met.

3.4.2.1 In the aft critical loading, with the aircraft trimmed at the speeds listed in column 3 of table III, the variation of elevator control force with speed shall be a smooth curve, with a gradient which is stable through trim and remains stable throughout the specified speed range. In configurations PA and P (climb), a reversal in slope may be permitted below the trim speed; if a reversal does occur, however, the force shall not decrease to less than one pound. This requirement applies throughout the speed ranges listed in column 2 of table III, but need be considered only at speeds within ±15 per cent (or ±50 knots, whichever is less) of the trim speed, and need not be considered at speeds where the control force exceeds 50 lb. As used in this paragraph, the term gradient shall not include that portion of the force versus speed curve within the preloaded breakout force or friction range.

3.4.3 Exception in Transonic Flight. - The requirements of paragraphs 3.4.1 and 3.4.2 may be relaxed, if necessary, in the transonic-speed range, provided that any reversals in slope of elevator angle or elevator control force with speed are mild and gradual and not seriously objectionable to the pilot. The relaxation of paragraph 3.4.1 is not intended to preclude paragraph 3.4.1.1, which shall remain applicable throughout the entire speed range (it is considered that a force reversal greater than 10 lb. or a gradient greater than 3 lb. per incremental M of 0.01 would be excessive).

TABLE III

Required Conditions for Longitudinal Static Stability

Configuration	Speed range	"Trim Speeds" 1/ for elevator-free stability
CR	$1.4V_{S_G}$ to V_{NRP}	Speed for maximum range, 2 additional trim speeds
P	$0.75\ V_{NRP}$ to V_H	V_{NRP}, 1 additional trim speed
P (climb)	$0.85\ V_{R/C}$ or $1.15V_{S_G}$, whichever is greater, to $1.3\ V_{R/C}$	$V_{R/C}$
G	V_{S_G} to V_H	$1.4V_{S_G}$, 1 or more additional trim speeds
D	All speeds normally attained in configuration D dives	1 or more representative configuration D dive speeds
L	V_{S_L} to limit structural speed in configuration L	$1.4\ V_{S_L}$
PA	V_{S_L} to limit structural speed configuration PA	$1.15\ V_{S_L}$

1/ Additional "trim speeds" shall be so selected that the trim speeds effectively span the specified speed range.

3.4.4 Stability in Accelerated Flight. - The slope of the curve of elevator deflection versus normal acceleration (g) at constant speed shall be stable (increasing up-elevator required for increasing g) throughout the range of attainable load factors in all configurations and in all conditions of flight.

3.4.5 Short-period Oscillations. - The dynamic oscillations of normal acceleration which occur at approximately constant speed and which may be produced by abruptly deflecting and returning the longitudinal control to the trimmed position shall meet the requirements of the accompanying figure 5 for configuration P. For configuration PA, the damping ratio shall be at least 0.055 for periods of less than five seconds. If small amplitude residual oscillations exist, they shall not affect the utility of the aircraft.

3.4.5.1 When the elevator is abruptly deflected and released, the motion of the elevator following the release shall be essentially deadbeat, unless the elevator oscillations are of such frequency and amplitude that they do not result in an objectionable oscillation in normal acceleration.

3.4.5.2 There shall be no tendency for a sustained or uncontrollable oscillation resulting from efforts of the pilot to maintain steady flight.

3.4.5.3 The requirements of paragraphs 3.4.5, 3.4.5.1, and 3.4.5.2 shall apply at all permissible airspeeds and loadings, both in straight flight and in turns.

3.4.6 Long-period Oscillations. - Although positive damping of the conventional long-period, or phugoid, oscillation is desired for all conditions, a negative damping ratio of -0.10 is acceptable provided the period of the oscillation is 10 seconds or longer. any oscillation having a period greater than five seconds, but less than ten seconds, shall have a damping ratio no less than zero.

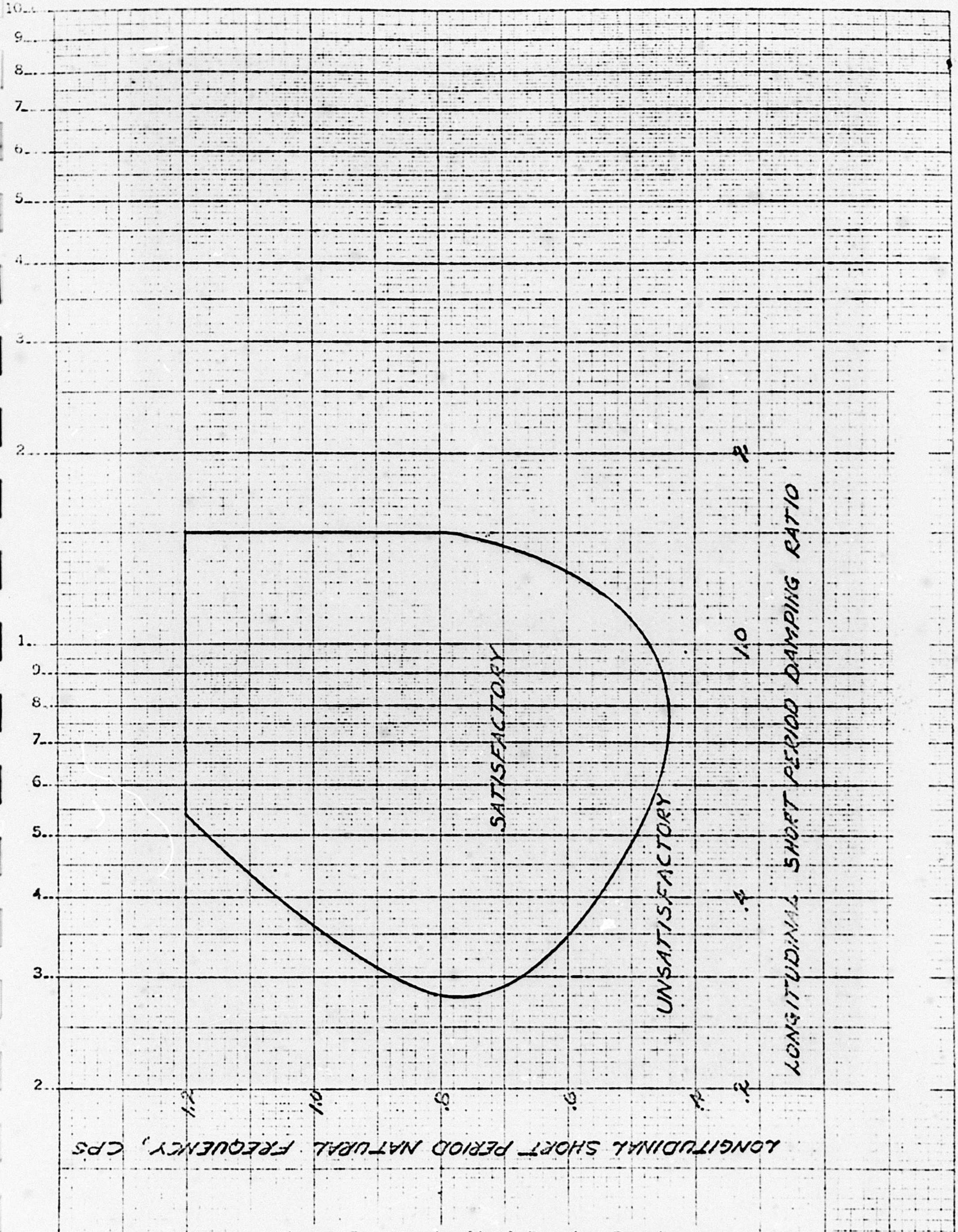

Figure 5. Longitudinal Damping Requirements

For the period range wherein essentially zero damping of the phugoid is tolerated, the longitudinal short period must be satisfactorily damped.

3.4.7 Control Effectiveness in Unaccelerated Flight. - In erect unaccelerated flight at any altitude, the attainment of any permissible speed above $V_{conversion}$ shall not be limited by the effectiveness of the longitudinal control, or controls. This requirement shall apply to all aircraft configurations and permissible loading.

3.4.8 Control Effectiveness in Accelerated Flight. - In the forward critical loading, when trimmed at any permissible speed and altitude in the configurations listed in table III, it shall be possible to develop at the trim speed, by the use of the elevator control alone, the limit load factor, the lift coefficient corresponding to V_S as defined in paragraph 3.10.2 or 3.10.2.2, or a load factor consistent with the operational flight envelope specified in paragraph 3.1.4.2.

3.4.9 Control Forces in Steady Accelerated Flight. - In steady turning flight and in pullouts, increases in pull force shall be required to produce increases in positive normal acceleration throughout the range of attainable accelerations. The variation of force with normal acceleration at all points beyond the breakout force shall be approximateyy linear, except that an increase in slope upward (such as might be introduced by an acceleration restrictor) is permissible above 0.85 n_L. In general, a departure from linearity resulting in a local gradient which differs from the average gradient by more than 50 per cent is considered excessive. The average force gradient shall be within the limits specified in table IV in configurations P and PA throughout the operational flight envelope up to 0.85n_L.

3.4.9.1 I[illegible]onfigurations at all permissible speeds and accelerations, the local value of the force gradient shall never be less than three pounds per g.

TABLE IV

Elevator control force gradient limits, pounds per g

Maximum	Minimum
$\frac{56}{n_L-1}$	$\frac{21}{n_L-1}$

3.4.9.2 Under conditions in which maximum attainable normal acceleration is less than n_L (e.g., limited by stall or control effectiveness), an increase in the maximum force gradient up to a value no higher than 50 per cent greater than that specified in table IV may be permitted.

3.4.9.3 The requirements of paragraph 3.4.9 apply to negative as well as positive accelerations except that the maximum force gradients specified in table IV may be exceeded in the negative acceleration range. This increase, however, shall not exceed 50 per cent of the value specified in table IV.

3.4.10 Control Forces in Sudden Pull-ups. - In sudden pull-ups from trimmed straight flight, in which the elevator cockpit control is rapidly deflected and returned to its initial position, the ratio of the maximum elevator control force to maximum (peak) change in normal acceleration shall never be less than the ratio of force to acceleration change obtained in steady accelerations under the same conditions. In investigating the sudden pull-up, several rates of cockpit control motion shall be considered (e.g., the elapsed time from start to return varying from 1/2 second to six seconds).

3.4.11 Control Effectiveness in Takeoff. - Elevator effectiveness shall not unduly restrict the takeoff performance of the aircraft. As a minimum, it shall be possible to obtain takeoff

attitude on a hard-surface runway at a minimum speed no greater than $V_{S_{TO}}$. This requirement shall be met with the aircraft loading which produces the most critical nose-heavy moment. The loadings considered for this purpose shall include all full and partial loads which might normally be encountered during the flight research testing of the aircraft.

3.4.12 Control Forces in Takeoff. - With trim optional but constant, the longitudinal control forces required for takeoffs and the ensuing acceleration to the speed for minimum drag shall not exceed 20 pounds pull or 10 pounds push.

3.4.13 Control Effectiveness in Landing. - At the forward critical loading with the aircraft trimmed at the approach speed in configuration PA, longitudinal control shall be sufficiently effective in order that in configuration L, V_{S_L} can be obtained in close proximity to the ground.

3.4.14 Control Force in Landing. - It shall be possible to meet the landing requirement of 3.4.13 with a longitudinal control pull force not exceeding 20 pounds with the aircraft trimmed for the approach speed.

3.4.15 Control Forces in Dives. - With the aircraft trimmed initially in level flight at V_H, but with trim optional in the dive, it shall be possible to maintain the elevator control forces within the limits of 50 lb. push or 35 lb. pull in dives to any attainable speed within the maximum permissible speed envelope. The forces required for recovery from these dives (see paragraph 3.1.5) shall not exceed 120 lbs. Trim may be used to assist in recovery provided that no unusual pilot technique is required.

3.4.16 Effects of Deceleration Device. - Deployment or jettison of the drag parachute provided for deceleration and descent shall not result in excessive trim changes or dangerous aircraft behavior. It is desired that employment of the device shall produce a positive increment of normal acceleration, and the total normal load factor resulting from deployment or jettison of the device shall never be greater than $0.8n_L$ in a positive or negative direction, controls free, at the most aft critical loading.

3.4.17 Longitudinal Trim Changes. - The longitudinal trim changes caused by changes in power, flap setting, gear operation, etc., shall not be so large that peak longitudinal control forces in excess of 10 lb. are required when such configuration changes are made in flight under conditions representative of operational procedure. Generally, the conditions listed in table V will suffice for determination of compliance with this requirement. With the aircraft trimmed for each specified initial condition, the peak force required to maintain the specified constant parameter following the specified configuration change shall not exceed 10 lb. push or pull. This requirement shall apply to a time interval of at least five seconds following the completion of the pilot action initiating the configuration change. The magnitude and rate of trim change subsequent to this time period shall be such that the forces are easily trimmed by use of the normal trimming devices.

3.4.18 Longitudinal Trim Change Caused by Sideslip. - With the aircraft trimmed for straight flight in each of the configurations and at the trim speeds specified in table III, the longitudinal control force required to maintain constant speed in sideslips shall not exceed numerically the lowest force, which, in the same configuration, would produce a normal acceleration change of 1.0g in the accelerated maneuvers of paragraph 3.4.9. In no event, however,

shall the force exceed 10 lb. pull or 3 lb. push. The sideslips considered shall include angles up to the largest obtainable with 50 lb. of rudder pedal force applied in either direction for wings-level trimmed flight. If a variation of longitudinal control force with sideslip does exist, it is preferred that increasing pull force accompany increasing sideslip, and that the magnitude and direction of the trim change be similar for right and left sideslips.

TABLE V

Longitudinal Trim Change Conditions

Condi-tion No.	Altitude	Initial Trim Condition				Configu-ration change	Parameter to be held constant
		Speed	Gear	Flaps	Power		
1	Low	$1.4V_{S_G}$	Up	Up	PLF	Gear down	Altitude
2	Low	$1.4V_{S_G}$	Down	Up	PLF	Flaps down	Altitude
3	Low	$1.4V_{S_L}$	Down	Down	PLF	Idle Power	Speed
4	Low	1/ $1.15V_{S_L}$	Down	Down	PLF	Takeoff Power	Altitude
5	Low	$1.3V_{S_{TO}}$	Down	Takeoff	Take-off	Gear Up	Rate of Climb
6	Low	$1.5V_{S_{TO}}$	Up	Takeoff	Take-off	Flaps Up	Rate of Climb
7	Medium, high	Level flight	Up	Up	MRP	Idle Power	Altitude

1/ Normal approach speed, if lower than $1.15V_{S_L}$

3.5 Lateral and Directional Stability and Control, Lift-fan Operation. -

3.5.1 <u>Directional Control During Taxiing</u>. - Directional control shall be sufficiently powerful, in order that its use with the other normal controls will permit easy execution of all normal taxiing maneuvers. In particular, the following ground handling conditions shall be met:

(a) It shall be possible, without the use of brakes, to maintain a straight path in any direction in a wind of 35 knots.

(b) It shall be possible to make a complete turn in either direction in a wind of 35 knots.

3.5.2 <u>Translational Flight</u>. - From the hovering condition, it shall be possible to obtain steady, level, translational flight at a sidewise velocity of 35 knots to both the right and the left. At the specified sidewise velocity and during the transition from hovering, the controls and the aircraft itself shall be free from objectionable shake, vibration, or roughness as specified in paragraph 3.8.1.

3.5.3 <u>Stability in Hovering Flight</u>. - The requirements of paragraph 3.3.2 shall be applicable to lateral and directional control motions as well as longitudinal.

3.5.4 <u>Control Margin</u>. - In all normal service loadings, including those resulting in asymmetrical lateral center of gravity locations and steady flight under the conditions specified in paragraphs 3.3.1 and 3.5.2, a sufficient margin of control effectiveness in excess of that required for trim, and at least adequate control to produce 10 per cent of the maximum attainable hovering rolling acceleration, shall remain.

3.5.5 Directional Control Power. - Directional control power shall be such that when the aircraft is hovering in still air at the design gross weight (out of ground effect), a rapid 1.0 inch step displacement from trim of the directional control shall produce a yaw displacement at the end of 1.0 second which is at least $110/(W + 1000)^{1/3}$ degrees. When maximum available displacement from trim of the directional control is rapidly applied at the conditions specified above, the yaw angular displacement at the end of 1.0 second shall be $330/(W + 1000)^{1/3}$ degrees. In both equations, W represents the design gross weight of the aircraft in pounds.

3.5.6 Directional Control in Crosswind. - It shall be possible to execute a complete turn in each direction while hovering over a given spot at the design gross weight (in and out of ground effect), in a wind of at least 35 knots. To insure adequate margin of control during these maneuvers, sufficient control shall remain at the most critical azimuth angle relative to the wind, in order that, when starting at zero yawing velocity at this angle, the rapid application of full directional control in the critical direction results in a corresponding yaw displacement of at least $110/(W + 1000)^{1/3}$ degrees in the first second, where W represents the design gross weight of the aircraft in pounds.

3.5.7 Oversensitivity in the Directional Control. - Response of the aircraft to directional control deflection as indicated by the maximum rate of yaw per inch of sudden pedal displacement from trim while hovering, shall not be so high as to cause a tendency for the pilot to overcontrol unintentionally. In any case, the sensitivity shall be considered excessive if the yaw displacement is greater than 50 degrees in the first second following a sudden pedal displacement of 1 inch from trim while hovering at the lightest normal service loading.

3.5.8 <u>Sideslip Characteristics</u>. - The aircraft shall possess positive, control-fixed, directional stability, and effective dihedral at all forward speeds above 50 knots in level flight and in partial power descents. At these flight conditions with zero yawing and rolling velocity, the variations of pedal displacement and lateral control displacement and the corresponding control forces with steady sideslip angle shall be stable (left pedal and right stick displacements and forces for right sideslip) up to full pedal displacement in both directions, but not necessarily beyond a sideslip angle of 15 degrees at $V_{conversion}$, 45 degrees at the low speed given above, or beyond a sideslip angle determined by a linear variation with speed between these two angles. Between sideslip angles of ± 15 degrees, the curve of pedal displacement and lateral control displacement and the corresponding control forces plotted against sideslip angle shall be approximately linear. In all flight conditions specified above, a 10 per cent margin of longitudinal and lateral control effectiveness (as defined in paragraphs 3.3.1 and 3.5.4), shall remain.

3.5.8.1 At the conditions specified in paragraph 3.5.8, it shall be possible to make complete turns in each direction with pedals free. At all speeds specified in paragraph 3.5.8, no reversal of rolling velocity (i.e., return through zero) shall occur after a small lateral step displacement of the control stick is made with pedals free. The stick deflection chosen should be such that the maximum angle of bank reached during 6 seconds is approximately 30 degrees. This requirement is intended to apply to angular velocity type controls.

3.5.8.2 During pedal-fixed rolling maneuvers, there shall be no objectional adverse yaw.

3.5.9 <u>Control Force Characteristics</u>. - At the trim conditions and speeds specified in paragraph 3.7.4, the lateral force gradient for the first inch of travel from trim shall be no less than 0.5 pounds per inch, and no more than 2.0 pounds per inch. In addition, however, the force produced for a 1 inch travel from trim by the gradient chosen shall not be less than the breakout force (including friction) exhibited in flight. The slope of the curve of stick force versus displacement shall be positive at all times and the slope for the first inch of travel from trim shall always be greater than or equal to the slope for the remaining stick travel. The directional control shall have a limit force of 15 pounds at maximum deflection with a linear force gradient from trim position. There shall be no undesirable discontinuities in either the lateral or directional force gradients.

3.5.9.1 From trimmed initial conditions, the lateral and directional control forces required for the performance of the maneuvers discussed in paragraphs 3.3.5, 3.5.1, 3.5.2, 3.5.4, 3.5.5, 3.5.6, and 3.5.8.1, shall conform with the values given in table II.

3.5.10 <u>Control Force Transients</u>. - Controls shall be free from objectionable transient forces in any direction following rapid lateral stick or pedal deflections. During and following a rapid lateral displacement of the control stick from trim or a rapid pedal displacement from trim, the force acting in a direction to resist the displacement shall not at any time fall to zero. Lateral control displacement shall not produce longitudinal control forces in excess of 40 per cent or pedal forces in excess of 100 per cent of the associated lateral force. Pedal displacement shall not produce longitudinal control forces in excess of 8 per cent or lateral control forces in excess of 6 per cent of the associated pedal force. For aircraft employing power-boosted or power-operated controls, there shall be no longitudinal control forces developed in conjunction with lateral or directional control displacement.

3.5.11 Excessive Sensitivity of Lateral Control. - The response of the aircraft to lateral-control deflection, as indicated by the maximum rate of roll per inch of sudden control deflection from the trim setting, shall not be so high as to cause a tendency for the pilot to overcontrol unintentionally. In any case, at all level flight speeds, including hovering, the control effectiveness shall be considered excessive if the maximum rate of roll per inch of stick displacement is greater than 20 degrees per second.

3.5.12 Control Response. - There shall be no objectionable or excessive delay in the development of angular velocity in response to lateral or directional control displacement. The angular acceleration shall be in the proper direction within 0.2 second after control displacement. This requirement shall apply for all flight conditions specified in paragraph 3.3.1.

3.5.13 Trim Changes. - The aircraft shall not exhibit excessive lateral trim changes with changes in power or height control, or both. Specifically, when starting from trim at any combination of power and airspeed within the flight envelope of the aircraft, it shall be possible to maintain lateral trim with a control displacement amounting to no more than 2 inches from the initial trim position as the engine throttle(s) or height control or both are varied either slowly or rapidly in either direction throughout the available range.

3.5.14 Lateral Control Power. - Lateral control power shall be such that when the aircraft is hovering in still air at the design gross weight (out of ground effect), a rapid 1 inch step displacement from trim of the lateral control shall produce an angular displacement at the end of one-half second of at least $32/(W+1000)^{1/3}$ degrees. When maximum available motion from trim of the lateral control is

rapidly applied at the conditions specified above, the resulting angular displacement at the end of one-half second shall be at least $96/(W + 1000)^{1/3}$ degrees. In both expressions, W represents the design gross weight of the aircraft in pounds.

3.5.15 Roll and Yaw Damping. - To insure satisfactory transient response characteristics following either a lateral or directional control input and to minimize the effect of external disturbances, the aircraft shall exhibit roll angular velocity damping (that is, a moment tending to oppose the angular motion and proportional in magnitude to the rolling angular velocity) of at least $25 (I_x)^{0.7}$ ft-lb/rad/sec., where I_x is the moment of inertia about the roll axis expressed in slug-ft^2. The yaw angular velocity damping shall be at least $27 (I_z)^{0.7}$ ft-lb/rad/sec., where I_z is the moment of inertia about the yaw axis expressed in slug-ft^2.

3.5.16 Dynamic Stability Characteristics. - The aircraft shall exhibit satisfactory lateral-directional dynamic stability characteristics following a disturbance in forward flight. Lateral-directional oscillations with controls fixed following a disturbance shall exhibit the following characteristics:

(a) Any oscillation having a period of less than 5 seconds shall damp to one-half amplitude in not more than one cycle. There shall be no tendency for undamped small amplitude oscillations to persist.

(b) Any oscillation having a period greater than 5 seconds but less than 10 seconds shall damp to one-half amplitude in not more than two cycles. There shall be no tendency for undamped oscillations to persist.

(c) Any oscillation having a period greater than 10 seconds but less than 20 seconds shall be at least lightly damped.

(d) Any oscillation having a period greater than 20 seconds shall not achieve double amplitude in less than 20 seconds.

3.5.17 Instability in Ground Effect. - Lateral instability with angle of bank when in ground effect shall be minimized, and lateral control shall be at least adequate to maintain the angle of bank within ±5 degrees when in ground effect with a minimum amount of lateral stick motion required.

3.5.18 Control System Adjustability. - The directional and lateral control systems shall, in addition to providing the characteristics given above, permit the investigation in hovering flight of the effect of variation in control sensitivity, damping level, and control power. In particular, adjustability of damping level and stick sensitivity shall be provided to meet lateral control criteria given as desirable in figure 4. Similarly, control system adjustability in yaw shall be provided to yield a control power/inertia ratio of 1 ft-lb./inch/slug-ft^2 and a damping/inertia ratio of 2 ft-lbs/rad/sec/slug-ft^2. Directional and lateral controls shall also be capable of generating terminal angular velocities in yaw and roll during hovering flight of 50 and 30 degrees per second, respectively. Further, the control system shall permit adjustment to reduced directional and roll control powers and damping levels to permit general investigation of aircraft handling qualities in hovering flight.

3.5.19 Directional Control During Short Takeoff and Landing. - Short field takeoff and landing requirements shall be referenced to operation over a 50 ft. obstacle as specified in paragraph 3.3.13.

3.5.19.1 For STOL operation at the minimum operating speed, directional control power shall be sufficient to permit development in the critical direction of at least 10° sideslip angle or to the maximum value specified in normal operation for crosswind landings.

3.5.19.2 For STOL operation, the directional control in conjunction with other normal means of control shall be adequate to maintain straight paths on the ground during taxi, and normal takeoffs and landings in winds in any direction up to a wind velocity of 35 knots. This requirement shall be met with not more than 180 lbs. pedal force.

3.5.20 Lateral Control During Short Takeoffs and Landing. - Short field takeoff and landing requirements shall be referenced to operation over a 50 ft. obstacle as specified in paragraph 3.3.13.

3.5.20.1 For STOL operation, the aircraft shall be capable of attaining a bank angle of at least $81/(W + 1000)^{1/3}$ degrees within 1/2 second of initiation of abrupt, full lateral control displacement. In obtaining the required roll performance, the directional control may be held fixed or may be employed to reduce adverse yaw (not to produce favorable yaw). This requirement shall apply to the loading condition which produces the most critical rolling moment of inertia.

3.5.20.2 There shall be no objectionable non-linearities in the variation of rolling response with lateral control deflection or force which would cause over-sensitivity or sluggishness in response to small pilot commands. In addition, there shall be no objectionable or excessive delay in the development of angular velocity in response to lateral control deflection. Angular acceleration shall be in the proper direction within 0.2 second after the initiation of pilot control action.

3.6 Lateral and Directional Stability and Control, Conventional Operation. -

3.6.1 Damping of the Lateral-directional Oscillations. - In the configurations and over the speed ranges specified for longitudinal stability (table III), the damping of the lateral-directional oscillations, with the cockpit controls fixed or free, shall meet the requirements of curve A shown in figure 6. Residual undamped oscillations may be tolerated only if the amplitude is sufficiently small that the motions are not objectionable. Generally, the conditions listed in table VI will suffice for determination of compliance with these requirements.

3.6.2 Spiral Stability. - Spiral stability is not required, but if the spiral motion is divergent, the rate of divergence shall not be so great that, following a small disturbance in bank with controls fixed, the bank angle is doubled in less than 20 seconds in the PA and CR conditions of table VI, or four seconds in any of the other flight conditions of table III.

TABLE VI

Flight conditions for investigation of lateral-directional damping

Configuration	Altitude	Speed
CR	Medium, high	Speed for maximum range
P	Low, medium, high	Speed for level flight
D	Medium, high	$0.9\ V_H$
PA	Low	$1.15V_{S_L}$
L	Low	$1.4V_{S_L}$

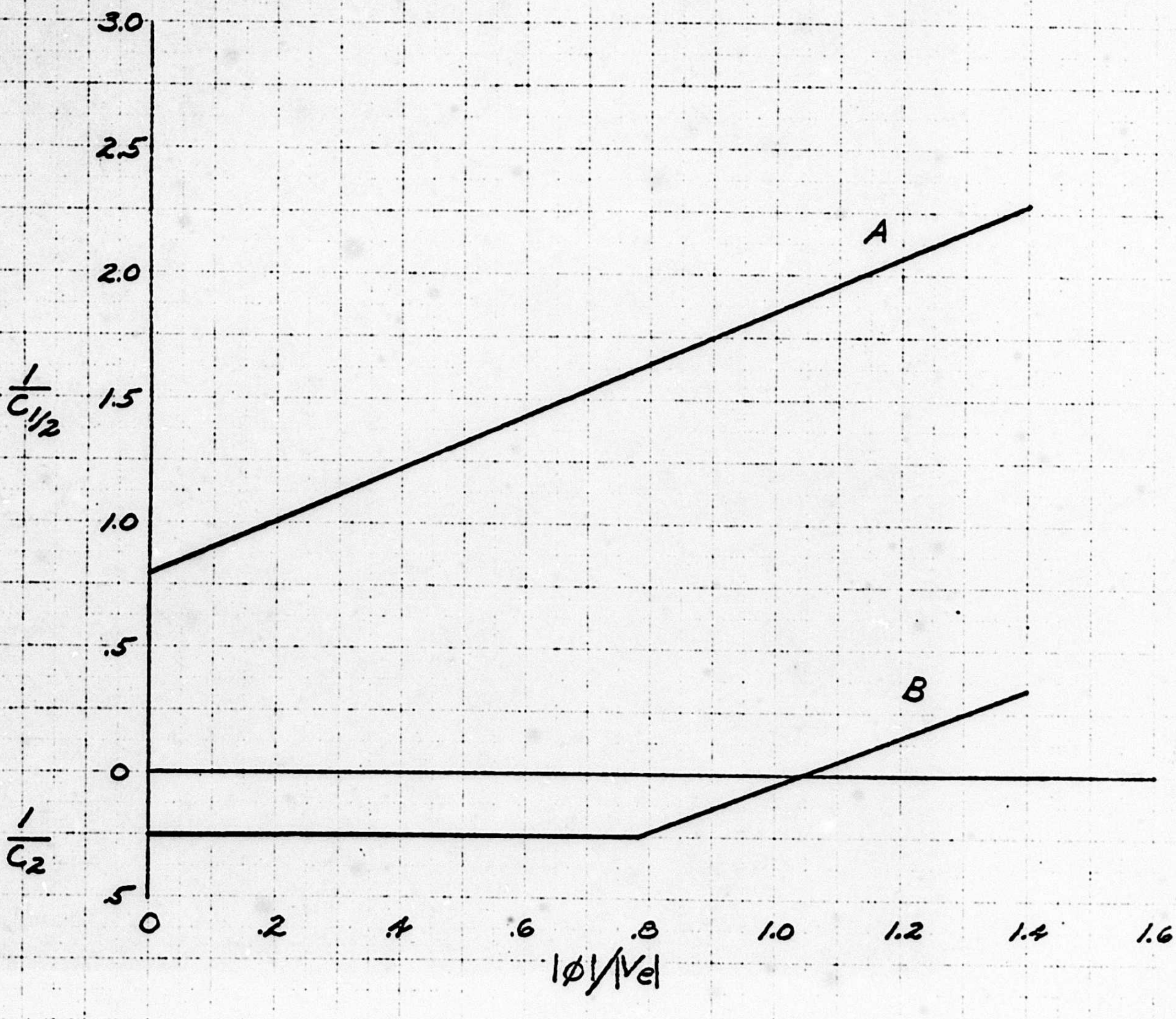

Figure 6. Lateral-Directional Damping Requirements

3.6.3 Steady Sideslip Conditions. - Requirements for static directional stability, dihedral effect, and side force variation are expressed in terms of characteristics in steady sideslips. Unless otherwise stated, such requirements shall apply in straight-path (zero turn rate) sideslips up to the sideslip angles produced by full rudder deflection, 250 lb. of rudder force, or full aileron deflection whichever is reached first. The requirements shall be met at the lightest normal service loading, in the configurations and speed ranges specified in table III, with the aircraft trimmed for wings-level straight flight. In addition, the requirements shall be met in configuration WO at all permissible speeds above $V_{S_{PA}}$, with the aircraft trimmed for wings-level straight flight at $1.15V_{S_L}$ in configuration PA. Although the requirements apply over the entire specified speed range, investigation at the trim speeds specified in table III, and at $1.15V_{S_L}$ in configuration WO, will ordinarily suffice for determination of compliance.

3.6.4 Static Directional Stability Rudder Position. - The aircraft shall possess rudder-fixed directional stability such that, in the sideslips specified in paragraph 3.6.3, right rudder pedal deflection from wings-level position is required in left sideslips, and left rudder pedal deflection is required in right sideslips. For angles of sideslip between ±15 degrees from the wings-level condition, the variation of sideslip angle with rudder pedal deflection shall be essentially linear. Throughout the remainder of the range of required pedal deflections, an increase in pedal deflection shall always be required for an increase in sideslip.

3.6.5 Static Directional Stability (Rudder Force). - The aircraft shall possess rudder-free stability such that, in the sideslips specified in paragraph 3.6.3, right rudder force is required in left sideslip and left rudder force is required in right sideslip. For angles of sideslip between ±15 degrees from the wings-level, straight-flight condition, the variation of sideslip angle with rudder force shall be essentially linear. At greater angles of sideslip, a lightening of the rudder force is acceptable, but the rudder force shall never reduce to zero or overbalance.

3.6.6 Dihedral Effect (Aileron Position). - The aircraft shall exhibit positive control-fixed dihedral effect as indicated by the variation of aileron cockpit control deflection with sideslip in the sideslips specified in paragraph 3.6.3. Left aileron deflection shall be required for left sideslip, and right aileron deflection shall be required for right sideslip.

3.6.6.1 Configuration WO may, if necessary, be excepted from the requirement of paragraph 3.6.6. The aileron cockpit control deflections required in the sideslips of paragraph 3.6.3, however, shall never exceed one-half of full deflection in the negative-dihedral direction.

3.6.6.2 The positive effective dihedral shall never be so great that more than 75 percent of full aileron cockpit control deflection is required in any of the sideslips specified in paragraph 3.6.11 or in the sideslips specified in paragraph 3.6.3 up to the sideslip angles which might be required in normal operation.

3.6.6.3 Throughout rolls similar to those required in paragraph 3.6.16.1 but performed with the rudder free, the rolling velocity shall always be in the proper direction.

3.6.7 Dihedral Effect (Aileron Force). - The aircraft shall exhibit positive control-free dihedral effect as indicated by the variation of aileron control force with sideslip in the sideslips specified in paragraph 3.6.3. Left aileron control force shall be required for left sideslip, and right aileron control force shall be required for right sideslip. The variation of aileron control force with sideslip angle shall be essentially linear. The aileron force required in the sideslips specified in paragraph 3.6.11 shall not exceed 10 lb.

3.6.7.1 Configuration WO may, if necessary, be excepted from the requirements of paragraph 3.6.7. The aileron control forces required in the sideslips specified in paragraph 3.6.3, however, shall never exceed 10 lb. in the negative-dihedral direction.

3.6.8 Side Force in Sideslips. - The side force characteristics shall be such that in the sideslips specified in paragraph 3.6.3, an increase in right bank angle accompanies an increase in right sideslip, and an increase in left bank angle accompanies an increase in left sideslip.

3.6.9 Adverse Yaw. - The angle of sideslip developed during a rudder-pedal-fixed abrupt roll out of a trimmed, level, steady 45-degree banked turn at $1.4V_{S_{CR}}$ in configuration CR, and at $1.4V_{S_{PA}}$ in configuration PA, shall not exceed 15 degrees. The roll shall continue until a bank angle of 45 degrees is reached in the opposite direction. The aileron deflection held during the roll shall be at least that required for compliance with the lateral control requirements of paragraph 3.6.16.1. In similar rolls with partial aileron deflections, the angle of sideslip shall be proportional to the aileron cockpit control deflection. If an automatic turn coordination device is employed, the rudder pedals may be free rather than fixed during the roll.

3.6.10 Asymmetric Power (Rudder Free). - Aircraft motions following sudden failure of one engine shall be such that dangerous flight conditions can be avoided by normal pilot corrective control action. As a measure of compliance with this requirement, the following conditions shall be fullfilled: In configuration P, with the most critical engine inoperative (with rpm simulating the static condition after an engine has failed in flight with no corrective action unless automatically provided), and with the other engine developing normal rated power, it shall be possible at all speeds above $V_{conversion}$ with rudder free to maintain steady straight flight by sideslipping and banking. The weight shall be that corresponding to the lightest normal service loading, and trim shall be as required for wings-level straight flight with symmetric power.

3.6.11 Directional Control (Symmetrical Power). - Directional control shall be sufficiently effective to maintain wings-level straight flight in the configurations and over the speed ranges specified in table III with rudder forces no greater than 100 lb. When the aircraft is trimmed directionally at the trim speeds specified in table III, directional control power shall be sufficient to permit development in the critical direction of at least 10 degrees sideslip angle in configuration L at $1.1V_{S_L}$ or to the maximum value specified in normal operation for cross-wind landings at the minimum operating speed. In configuration WO at the lightest normal loading, directional control shall be sufficiently effective to maintain $V_{S_{P_A}}$ with rudder control force not exceeding 100 lb. when trimmed at the approach speed.

3.6.12 Directional Control (Asymmetric Power). - In configuration TO with the most critical outboard engine inoperative (with rpm simulating failure in flight with no corrective action unless automatically provided), it shall be possible, at the lightest normal takeoff loading and with takeoff power on the remaining engine, to achieve and maintain straight flight with a bank angle not greater than 5 degrees, at all speeds above minimum takeoff speed. Automatic devices which normally operate in the event of power failure may be used. With trim settings normally employed in symmetric power takeoff, the rudder pedal force required to maintain straight flight with asymmetric power, as defined above, shall not exceed 180 lb. In addition, a sufficient margin of directional control shall be available to perform a standard rate turn (3° per sec.) in the critical direction.

3.6.13 Directional Control During Takeoff and Landing. - The rudder control, in conjunction with other normal means of control shall be adequate to maintain straight paths on the ground during taxi and normal takeoffs and landings in winds in any direction up to a wind velocity of 35 knots. This requirement shall be met with no more than 180 lb. pedal force.

3.6.14 Directional Control To Counteract Adverse Yaw. - In maneuvers described in paragraph 3.6.9, but with the rudder employed for coordination rather than held fixed, directional control effectiveness shall be adequate to maintain zero sideslip, with rudder forces not greater than 180 lb.

3.6.15 Directional Control in Dives. - When trimmed directionally at the service ceiling in configuration P, the rudder control shall be capable of maintaining zero sideslip throughout the dives and pullouts of paragraph 3.4.15 without exceeding 50-lb. rudder pedal force.

3.6.16 Lateral Control. - Lateral control shall be adequate for compliance with the rolling performance specified below. In those requirements involving measurement of time, the time shall be measured from the instant of initiation of pilot control action. In obtaining the required roll performance, the rudder pedals may be held fixed or may be employed to reduce adverse yaw (not to produce favorable yaw).

3.6.16.1 In configurations L, PA, and WO at the trim speeds specified for longitudinal stability in table III, the aircraft shall be capable of obtaining a bank angle $81/(W+1000)^{1/3}$ degree in 1/2 second. In configuration P over the speed range specified in table III, the aircraft shall be capable of obtaining a bank angle of at least 50 degrees but not greater than 160 degrees in one second with a roll time constant not exceeding 1.5 seconds.

3.6.16.2 There shall be no objectionable non-linearities in the variation of rolling response with lateral deflection or force causing over-sensitivity or sluggishness in response to small cockpit control deflections or forces. In addition, there shall be no objectionable or excessive delay in the development of angular velocity in response to lateral control deflection. The angular acceleration shall be in the proper direction within 0.2 second after the initiation of pilot-control action. This requirement shall apply to the loading condition which produces the most critical rolling moment of inertia and for all flight conditions specified for roll performance.

3.6.16.3 The peak lateral control force required to obtain the specified rolling performance shall not exceed 20 lb. at $0.8V_H$, the peak lateral control force required to obtain the specified rolling performance shall not be less than 10 lb.

3.6.16.4 Lateral control shall be sufficiently effective to balance the aircraft laterally under the conditions specified in paragraph 3.6.10, 3.6.11, 3.6.12, and 3.6.13, with an aileron control force not exceeding that specified in paragraph 3.6.16.3 (See also paragraphs 3.6.6.2 and 3.6.7).

3.6.16.5 When trimmed laterally at the maximum operating altitude in configuration P, lateral control effectiveness shall be adequate to maintain the wings level throughout the dives and pullouts of paragraph 3.4.15, with aileron control forces not exceeding 10 lb.

3.6.16.6 At all altitudes, lateral control at M_D shall be sufficient to produce a steady rolling velocity in the correct direction of at least 15 degrees per second without excessive pilot effort.

3.7 General Control and Trim-ability Requirements. -

3.7.1 Control for Spin Recovery. - For all aircraft capable of being spun, the spin characteristics shall be such that controls shall be adequate to provide consistent prompt recoveries from fully developed erect and inverted spins with power off. Recovery shall not require abnormal pilot effort, and recovery control forces shall not exceed 250 lb. (directional), 75 lb. (longitudinal), or 35 lb. (lateral).

3.7.2 Control for Taxiing. - It shall be possible to perform all normal taxiing operations without undue pilot effort or inconvenience.

3.7.3 Control Surface Oscillations. - All control surfaces, and surfaces such as flaps, thrust spoiler, etc., shall be free of any tendency toward undamped oscillations apparent to the pilot under the flight conditions specified herein.

3.7.4 **Primary Flight Control Trim-ability, Lift-fan Mode.** - Trimming devices shall be capable of reducing the longitudinal, directional, and lateral control forces to zero for all conditions and speeds specified in paragraphs 3.3.1 and 3.5.2.

3.7.5 **Primary Flight Control Trim-ability, Conventional Mode.** - Trimming devices shall be capable of reducing the elevator, rudder, and aileron control forces to zero at all speeds between the minimum trim speeds specified in table VII and the upper limits of the speed ranges specified in table III. In addition, the rate of operation and the effectiveness of the longitudinal trim device shall be such that the elevator control force can be maintained within 10 lb. push or pull throughout the dives specified in paragraph 3.4.15.

TABLE VII

Conditions for trimming to zero control forces

Condition	Configuration	Minimum Trim Speed
1	Configuration P, at forward and aft critical loading	$1.2V_{S_{CR}}$
2	Configuration L, at forward and aft critical loading	$1.4V_{S_L}$
3	Configuration PA, at forward and aft critical loading	1/ $1.4V_{S_L}$
4	Configuration CR, with most critical engine inoperative, wings level	Speed for max. range

1/ or normal approach speed, whichever is lower

(a) Vibration acceleration on all controls in any direction shall not exceed 0.4g for frequencies up to 32 cps and a double amplitude of 0.008 inch for frequencies above 32 cps; this requirement shall apply to all steady speeds from 10 knots rearward to $V_{conversion}$ and in slow and rapid changes from one speed to another and during changes from one steady acceleration to another.

(b) Vibration accelerations at the pilot and observer stations at all steady speeds between 10 knots rearward and $V_{conversion}$ shall not exceed 0.15g for frequencies up to 32 cps and a double amplitude of 0.003 inch for frequencies greater than 32 cps.

(c) Vibration characteristics at the pilot and observer stations shall not exceed 0.3g up to 44 cps and a double amplitude of 0.003 inch at frequencies greater than 44 cps during slow and rapid linear acceleration or deceleration from any speed to any other speed between 10 knots rearward and $V_{conversion}$.

3.8.2 Vibration During Control Application. - The magnitude of the vibratory force at the controls in any direction during rapid longitudinal or lateral stick deflection shall not exceed 2 pounds. Preferably, these vibratory forces shall be zero.

3.8.3 Mechanical Instability. - The aircraft shall be free from mechanical instability such as ground resonance and flutter, that influence aircraft handling qualities.

3.9 Miscellaneous Requirements - Lift-fan Operation. -

3.9.1 Landing and Takeoff Capability. - The aircraft shall be capable of making satisfactory landings and takeoffs. Specifically, the following conditions shall be met:

3.9.1.1 It shall be possible to make satisfactory, safe, vertical takeoffs and landings in steady winds up to 45 knots and winds with gusts up to 45 knots.

3.9.1.2 From a level paved surface, it shall be possible to make satisfactory, safe running takeoffs, up to ground speeds of at least 35 knots.

3.9.1.3 It shall be possible to make satisfactory, safe landings on a level paved surface up to ground speeds of at least 35 knots. This shall be construed to cover landings with 3 knots ground speed in any direction and up to a side drift of at least 6 knots when landing with a ground speed of 35 knots.

3.9.2 Priority of Control. - The maximum physical control potential inherently available using the fan controls shall be utilized in the attitude and height control systems. The utilization of the fan controls for attitude and altitude control shall be on a priority basis. While hovering, for all height control positions, at least one-half of full roll and yaw control power shall be available without loss of total combined fan lift.

3.9.3 Vertical Characteristics. - It shall be possible to maintain positive control of altitude within ±1.0 foot by use of the height control while hovering at constant power under the conditions of 3.3.2. This shall be accomplished with a minimum amount of height control motion required, and in any case, it shall be possible to accomplish this with less than ± 1/2 inch movement of the lift control stick.

3.9.4 Stabilization System. - A stabilization system shall be provided for lift-fan flight operations. This system shall increase the basic stability of the aircraft as required to provide flying qualities in accordance with the requirements given herein. The system shall consist of a primary and a secondary stability augmentation system. The secondary system shall be provided for use as a standby system in case of failure of the primary.

3.9.4.1 The primary stability augmentation system shall have stabilization gain adjustment features to meet requirements detailed herein. Damping and position gains shall be adjustable and adjustment shall be permitted by the pilot in flight.

3.9.4.2 The following additional basic conditions shall also be met:

(a) With the stabilization system equipment engaged, and from steady level flight for a period greater than 30 seconds, out-of-trim conditions upon failure of one complete system during the period of transfer from one system to another shall be such that following the failure, the resulting rates of yaw, roll, and pitch shall not exceed 10 degrees per second and the change in normal acceleration shall not exceed ± 1/2g. When engaging the stabilization system or when switching system operation between primary and standby, there shall be no apparent switching transients.

(b) It shall be possible on the ground, with the stabilization system equipment operating and engaged, to move the controls manually to all limits without exceeding the forces of table II.

(c) The aircraft shall, with the stabilization system equipment disengaged, possess a sufficient degree of stability and control to allow continuation of normal level flight and the maneuvering necessary to permit a safe landing under visual flight conditions.

(d) A significant margin of control power beyond that needed to overcome airframe instability under simple flight conditions shall be provided. For this purpose, sufficient control margin over the amount required to perform maneuvers and to accomplish stability augmentation shall be provided. Specifically, for pitch, roll and yaw control, the augmentation system in combination with pilot controlled inputs shall not utilize more than 50 per cent of the available control moment in the unstable direction from the trim position for straight level flight at a given speed when performing the following maneuvers:

(1) Steady level-flight turn at $V_{conversion}$ to maximum load factor attainable in actual operation or the design or placard load factor, whichever occurs first.

(2) Steady sideslips at the combinations of speed and sideslip angle set forth in paragraph 3.5.8.

3.10 Conventional Flight Stall Characteristics. -

3.10.1 Required Flight Conditions. - The requirements for stall characteristics in conventional flight shall apply at all permissible cg positions, for configurations G, CR, L, and PA in straight unaccelerated flight, and with normal acceleration up to the limits of the operational flight envelopes.

3.10.2 Definition of Stalling Speed, V_S. - The stalling speed, V_S, is defined as the minimum speed attainable in flight, and is normally associated with the breakdown of airflow over the wing immediately after attaining the maximum overall trimmed lift coefficient of the aircraft. In order to minimize dynamic lift effects, the rate of reduction of speed during an approach to the stall should be not greater than 1 knot per second. The complete stall is generally characterized by uncontrollable pitching or rolling, or by a decrease in normal acceleration in turning flight.

3.10.2.1 In case that the technique of paragraph 3.10.2 does not result in a true aerodynamic wing stall because of insufficient longitudinal control, the aircraft, at a given weight, will have a varying minimum speed depending upon the cg position. For purposes of this specification, the stalling speed, V_S, in this event shall be defined as the minimum speed attainable in the applicable configuration with the aircraft loaded at its aft critical loading.

3.10.2.2 In the event that considerations other than wing maximum lift or available longitudinal control determine the minimum useable flying speed in any configuration (e.g., ability to perform altitude corrections, ability to take wave off, visibility, etc.), the stalling speed V_S for that configuration shall, for the purposes of this specification, be defined as the minimum useable flying speed.

3.10.3 Stall-warning Requirements. - The approach to the complete stall shall be accompanied by an easily perceptible stall warning which occurs between 1.05 and 1.15 times the stalling speed in configurations G, L, and CR, and between 1.05 and 1.10 times the stalling speed in configuration PA, but in no case less than 5 knots above the stalling speed. Acceptable stall warning shall consist of shaking of the cockpit controls, buffeting, or both, or shaking of the aircraft.

3.10.3.1 Artificial stall warning closely simulating the warning required in paragraph 3.10.2 shall be permitted only if it can be shown that it is not feasible to provide aerodynamic stall warning.

3.10.3.2 In the case of limiting elevators described in paragraph 3.10.2.1, no stall warning is required provided a true aerodynamic stall cannot be obtained while loaded at the aft critical loading, and provided no dangerous flight characteristics or motions occur at the minimum attainable speed.

3.10.4 Requirements for Acceptable Stalling Characteristics. - Although it is desired that no nose-up pitch occurs at the stall, a mild nose-up pitch may be accepted, provided that no dangerous or seriously objectionable flight conditions result. The stall shall be considered unacceptable if the aircraft exhibits uncontrollable rolling or downward pitching at the stall in

excess of 30 degrees from level. These requirements shall apply not only to aircraft with conventional (maximum lift) stalling speeds, but also to complete stalls when attainable by any means on aircraft with stalling speeds as defined in paragraph 3.10.2.1 or 3.10.2.2.

3.10.4.1 It shall be possible to prevent the complete stall by normal use of the controls at the onset of the stall warning. In the event of a complete stall, it shall be possible to recover by normal use of the controls with reasonable control forces, and without excessive loss of altitude or buildup of speed.

3.11 Powered Controls. -

3.11.1 Normal Control System Operation. - The control system shall satisfy the requirements of this specification and applicable aircraft mechanical design requirements. The system shall be capable of providing rapid repeated control movements as might be required for operation of the aircraft in gusty or turbulent air.

3.11.2 Control Power or Boost System Failure. - Where power-operated control systems are employed, suitable means for control following complete loss of power-operated control shall be provided. Engine failure or electrical system failure, or both, shall not result in primary power-operated control system failure. When two or more completely independent power-operated control systems are employed, the design conditions shall be the loss of one independent system. The means for control following such failure (e.g., independent power-operated control, direct mechanical control) is referred to herein as the alternate control system. Rates of control motion attainable following transfer to the alternate control system shall be such that safe

operation of the aircraft is in no way compromised, and shall in no case be less than 50 per cent of the normal rates.

3.11.3 Transfer to Alternate Control System - Trim Change. - The trim change associated with transfer to the alternate control system, when such transfer is either caused by control system power failure or performed intentionally in accordance with routine procedure, shall never be such as to bring about dangerous flight conditions.

3.11.3.1 From trimmed level flight in the lift-fan mode at any speed, out of trim conditions resulting from transfer to the alternate control system shall be such that:

(a) With controls free for at least three seconds, the resulting rates of yaw, roll, and pitch shall not exceed ten degrees per second, and the change in normal acceleration shall not exceed ±0.5g.

(b) It shall be possible to continue level flight with zero sideslip with forces to operate the controls not exceeding 80 lb. for the rudder control, 25 lb. for the height and longitudinal controls, and 15 lb. for lateral control.

3.11.3.2 If two completely independent power-operated control systems are used for conventional operation, a transfer at cruising altitude in trimmed level flight in configuration P shall cause no perceptible trim change. If an alternate control system is not an independent power system, the out-of-trim conditions resulting from a transfer at cruising altitude in trimmed level flight in configuration P shall be within the following limits:

(a) With controls free, the resulting rate of roll in either direction shall not exceed five degrees per second; the change in normal acceleration shall not exceed ±0.5g.

(b) The rudder control force required to maintain zero sideslip shall not exceed 100 lb.

3.11.3.3 In conventional flight upon transfer to the alternate control system in configuration PA at $1.15V_{S_L}$, with trim set for zero control forces prior to transfer, it shall be possible to maintain aircraft attitude with elevator control forces not exceeding 20 lb., and rudder control forces not exceeding 50 lb.

3.11.4 Control on Alternate System Lift-fan Mode. - With the aircraft trimmed in steady level flight at 40 knots when using the alternate control system it shall be possible without retrimming to make a normal landing approach and landing with control forces not exceeding the limits given in 3.11.3.1 (b).

3.11.5 Control on Alternate System, Conventional Mode. - At maximum level flight speed at sea level in the forward critical loading, it shall be possible, with the primary control system inoperative, to obtain a normal acceleration of at least 3.0. Elevator control force in this maneuver with the aircraft trimmed for level flight shall not exceed 120 lb.

3.11.5.2 With the primary control system inoperative and the elevator control force trimmed to within 5 lb. at $1.4V_{S_L}$ in configuration PA, it shall be possible to execute a safe landing with elevator control forces not exceeding 35 lb.

3.11.5.3 With the primary control system inoperative, it shall be possible to perform the landing of paragraph 3.11.5.1 in a cross wind of 50 per cent of the value specified in paragraph 3.6.13 with rudder control forces not exceeding 180 lb.

3.11.5.4 With the primary control system inoperative, it shall be possible to obtain 50 per cent of the roll displacement requirements of paragraph 3.4.16.1 with aileron control forces not exceeding 30 lb. During these rolls, the aileron trim shall remain fixed in the wings-level setting, and requirements regarding use of rudder shall be as specified in paragraph 3.4.16.

3.11.6 Ability to Trim on Alternate System. - With the primary power-operated control systems inoperative, it shall be possible to trim steady longitudinal, lateral and directional control forces to zero under all conditions specified for trimming in paragraphs 3.7.4 and 3.7.5.

4.0 NOTES. -

4.1 Intended Use. - This specification contains the flying quality requirements for the XV-5A Flight Research Aircraft, and shall serve as design objectives and as criteria for use in stability and control calculations, analysis of wind tunnel test results, and flight testing and evaluation.

4.2 Definitions. - Terms and symbols used throughout this specification are defined as follows:

$V_{conversion}$	- Speed for conversion between lift-fan and conventional modes of operation.
$V_{R/C}$	- Speed for maximum rate of climb with normal rated power.
V_S	- See paragraph 3.10.2. The subscripts, e.g., G, L, etc., refer to the aircraft configurations described in paragraph 3.1.8.
M	- Mach number.
$V_H M_H$	- High speed, (Mach number) level flight, augmented power.
V_{NRP}	- High speed, level flight, normal rated power.
$V_D M_D$	- Maximum permissible speed (Mach number) as defined by the maximum permissible speed envelope of paragraph 3.1.5.
$V_M M_M$	- Maximum operational speed (Mach number) as defined by the maximum operational speed envelope of paragraph 3.1.4.2.
n	- Normal load factor, in g units, normal to body axis.

n_L - Limit load factor for a given loading based on structural considerations.

$C_{\frac{1}{2}}$ - Number of cycles for the lateral oscillations to damp to half amplitude.

ϕ - Bank angle, degrees.

β - Sideslip angle, degrees.

$\left| \frac{\phi}{\beta} \right|$ - Ratio of amplitudes of bank and sideslip angles in oscillatory mode.

$\left| \frac{\phi}{V_e} \right|$ - Rolling parameter, degrees/feet per second.

$$\left| \frac{\phi}{V_e} \right| = \frac{57.3}{V_e} \cdot \left| \frac{\phi}{\beta} \right|,$$ where V_e is equivalent airspeed in feet per second.

MRP - Military rated power, which is the maximum power (not including augmentation) at which the engine can be operated for a specified period.

NRP - Normal rated power, which is the maximum power at which the engine can be operated continuously.

PLF - Power for level flight at the specified condition.

Power and thrust - For reaction-type engines, the word "power" shall be replaced by the word "thrust" throughout the specification.

Control surface - An external surface or device which is positioned by a cockpit control, and which produces aerodynamic or jet-reaction type forces in such manner as to control the attitude of the aircraft. As used in this specification, the elevator, ailerons, and

rudder are the control surfaces or devices which are controlled by the stick and rudder pedals to provide longitudinal, lateral, and directional control, respectively.

Control-fixed - A condition where the pilot's cockpit control is held firmly at a given position. Elevator-fixed, rudder-fixed, and aileron-fixed refer to the condition of the individual cockpit control.

Control-free - A condition where the cockpit control is unrestrained by the pilot. Elevator-free, rudder-free, and aileron-free refer to the condition of the individual cockpit control.

Elevator-fixed neutral point - The cg position for zero elevator cockpit control travel with change in speed, in straight flight at constant throttle.

Elevator-free neutral point - The cg position for zero elevator control force with change of speed for trim, in straight flight at constant throttle.

Longitudinal or elevator control force - Component of applied force, exerted by the pilot on the cockpit control, in or parallel to the plane of symmetry, acting at the center of the stick grip in a direction perpendicular to a line between the center of the stick grip and the stick pivot.

Directional or rudder control force - Difference of push-force components, of the forces exerted by the pilot onthe rudder pedals, lying in planes parallel to the plane of symmetry, measured along lines connecting the foremost point of the seat (at mid-adjustment) and the normal points of application of the pilot's instep on the respective rudder pedals.

Lateral or aileron control force - For a stick control, the component of control force exerted by the pilot in a plane perpendicular to the plane of symmetry, acting at the center of the stick grip in a direction perpendicular to a line between the center of the stick grip and the stick pivot.

Aft critical loading - The normal service loading which results in a combination of weight and cg position producing minimum stability. (Ordinarily the lightest gross weight at which the most aft cg position can be obtained in a given configuration at a normal service loading.)

Forward critical loading - Ordinarily, the heaviest gross weight at which the most forward cg position can be obtained in a given configuration at a normal service loading.

Sideslip angle - Angle between the undisturbed flow and plane of symmetry of the aircraft, measured in a plane parallel to the relative wind and perpendicular to the plane of symmetry. Plus, or right sideslip, corresponds to incident flow approaching from the right side of the plane of symmetry.

Power off - Jet engines - Idling thrust

4.3 Rates of Operation of Auxiliary Aerodynamic Devices. - Although it has not been considered feasible to include in this specification quantitative requirements for rates of operation of trim tabs, trimable stabilizers, artificial feel trimmers, etc., or for rates of extension and retraction of flaps, etc., the influence of such rates on the flying qualities may be appreciable and is treated qualitatively in paragraph 3.2.3. In general, trim devices should be operable rapidly enough to enable the pilot to maintain trim under changing conditions as normally encountered in functional and tactical employment of the aircraft, and yet must not be so rapid in operation as to induce over sensitivity or trim precision difficulties under any flight condition. Flaps and other high lift devices should operate at a rate sufficient to permit transition into the high lift configuration without undue delay, and yet must not operate so rapidly as to cause sudden or erratic trim or lift changes.

4.4 Control Force Coordination. - The control forces required to perform maneuvers which are normal for the aircraft should have magnitudes which are related to the pilot's capability to produce such forces. As a tentative guide on this subject, it is desired that the relative magnitudes of control forces in coordinated maneuvers should be approximately in the ratio of 50,

175, and 25 pound (or 2:7:1) for elevator, rudder, and aileron force, respectively, for a stick-control aircraft. These ratios refer to the peak forces obtained when, starting from level flight in configuration P at medium altitude, a rolling pullout maneuver is performed in which approximately 2/3 of the available rolling velocity is obtained simultaneously with a normal load factor of approximately $1 + 2/3\ (n_L - 1)$, maintaining zero sideslip with the rudder.

4.5 Artificial Stability Devices. - In general, the use of artificial devices, such as rate dampers or static-stability augmenters, should be considered only when provision of the required degree of stability by aerodynamic or simple mechanical means, such as bob weights, down springs, spring tabs, etc., is shown to be impossible or impracticable. When artificial devices are employed, it is ordinarily desired that, subject to reasonable limitations on weight and complexity, the improvement in the affected flight characteristics be such that an appreciable margin is provided beyond the pertinent minimum requirements. When extensive automatic provisions are incorporated (e.g., automatic pilot with control-stick steering), the requirements of this specification will ordinarily be augmented by specifications governing the procurement of the specialized equipment.

4.6 Effects of Aeroelasticity, Control Equipment, Structural Dynamics, etc. - Since the effects of aeroelasticity, control equipment, and structural dynamics may exert an important influence on the aircraft flying qualities, such effects should not be overlooked in calculations or analyses directed toward investigation of compliance with the requirements of this specification.

4.7 Lateral Oscillations. - The inclusion of the roll parameter in the lateral-dynamic stability requirements of paragraph 3.6.1 is based on partial results of several research programs still in progress. Evidence indicates that for very short periods (i.e., below 1.8 seconds) and for values of $/ \phi /v_e /$ greater than 1.2, the desired damping may be considerably greater than that specified in figure 6. Pending the incorporation of later research results in the requirements, periods and rolling parameters in these areas should be treated with caution, with the values shown in figure 6 employed as minimums.

4.8 Control Position Measurement. - In this specification, requirements involving control position have generally been written in terms of cockpit control rather than surface deflection because of the more direct influence of cockpit controls in pilot impressions. Because of the more basic engineering significance of, and need for, surface deflection data, proof of compliance with such requirements will ordinarily be accepted in terms of surface deflections unless linkage pecularities, stretch, deformation, etc., appear to render such proof invalid.

4.9 Engine Considerations. - In certain of the flying qualities design requirements, effects of engine operation are obvious and are covered directly (e.g., trim changes with power, stability with various power settings, etc.). Secondary or less clearly defined effects of engine operation may have an important bearing on flight characteristics and should not be overlooked in design. These considerations include: Effects of engine control and response; effects of engine gyroscopic moments in aircraft dynamic motions; and effects of engine operation on spin characteristics and spin recovery.

4.10 Control System Characteristics. - As many arrangements of flight control systems are possible, considering direct-mechanical, power-boosted, fully-powered controls, artificial feel, artificial stabilization, autopilot tie-in, etc., that a limited set of requirements such as those specified in paragraph 3.2 hardly can be expected to rule out all undesirable characteristics. Some of the known important variables, even in a simple system, are: friction in the control valve; friction, flexibility, backlash, gear ratio, and inertia in the control system; viscous damping and preload in the control system or valve; rate limiting of the control actuator; and the level of aircraft static and dynamic stability. The introduction of nonlinear linkages or valve characteristics further multiplies the important variables. In general, the designer should make every effort to provide a linear or smoothly varying response to cockpit control deflection and to control force for all amplitudes of control input, including values of stick force within the range of allowable breakout forces (table I), and small control deflections such as those required in tracking. The phase lag between the cockpit control deflection or force and control surface deflection should be kept to a minimum for reasonable large amplitude motions at frequencies considerably above the aircraft natural frequencies, and should not increase unduly at very small control amplitudes.